Innovation Funding Incentive

Annual Report 2012/13

Electricity Transmission

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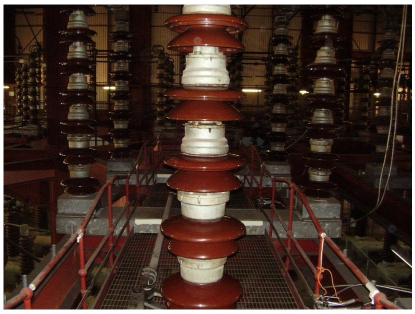
Project Title	Rapid Deployment Ballistic Screen			
Project Engineer	Graham Moss			
Description of project	This project is to deliver a cheap, effective and easily deployed ballistic screening module that is easily capable of withstanding the resulting debris from a typical catastrophic failure of porcelain clad high voltage (HV) transmission assets such as those seen in FMJL, FMVGs, SP2 breakers, bushings etc. It will be modular to cope with as small, or as large a deployment screen as required. Fully non-metal, it can be used within a live substation.			
Expenditure for financial year 12/13	Internal £8k External £14k Total £22k	Expenditure in previous (IFI) financial years	**Internal £5k** **External £129k** **Total 134k**	
Total project costs (collaborative + external + [company])	£156k	Projected 2013/14 costs	**£62k**	
Technological area and/or issue addressed by project	National Grid in the past has looked at the problem of screening from a very local viewpoint, and tended to rely on screening systems that are not capable of being easily transported, manoeuvred and put into the HV environment without outages, lifting equipment and substantial cost. The screening material under investigation is designed primarily to be completely effective in preventing all fragments of porcelain from a catastrophic failure at a distance of less than 10m. The system is designed to be modular, which means entire walls can be quickly assembled. The materials are to be extremely cost effective, relatively lightweight and will be designed to be easily fabricated to address several roles such as relay room protection, outer perimeter fence guards (for third party protection), window guards, safety 'pathways' through substations, wheeled screens for 'asap' coverage and emergency refuge shelters for those working within the substation, where travelling to a point of exit represents a danger in itself. The materials employed will be able to be 80% recycled (post use) on our substations as trench covers, with the lightweight transparent armour plate being recycled through normal recycling channels. It is thought that the main stay frame will be the only component that will require disposal or return to the manufacturer. The entire system will be completed from non-conductive components, and assembled by Redman Composites, who currently are building blast protection screens for the enhanced security projects at many London substations.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		14	0	**14**
Expected benefits of project	Direct intervention to protect personnel from potential harm when access through risk management hazard zones is absolutely necessary. Protection to secondary assets from debris, such as relay rooms, temporary buildings and windows. Condition Monitoring systems can assist in providing a warning of a potential failure, but the inception period from notification to failure is unknown. Ability to screen out the risk management hazard zone (RMHZ) in order to			

	access assets for maintenance / routines. **Ability to allow access through RMHZ for emergency repair work to other assets.** **Ability to reduce risk of debris leaving the substation and passing on to third party ground.** **Potential ability to look at safety screening for Mobile elevating work platforms (MEWPs).** **A scheme, addressing current transformer (CT) failures, costs £1m per year. An estimated 10% reduction in costs can reasonably be expected.**			
Expected timescale of project	1 year	Duration of benefit once achieved	**5 years**	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	**£65k**	
Potential for achieving expected benefits	**Based upon preliminary work into the proposed screens, we are confident of the materials ability to withstand three times the highest energy impacts seen in the controlled disruptive failures conducted by the Royal College or Military Science in mid-2000.** **The majority of this work is to focus on the high end testing by RADNOR who specialise in high energy impact physics and the work to turn plates of material into various types of protective screen for a multitude of applications.** **Based on these aspects we are confident that the project will be a success.**			
Project progress [Year to End of March 2013]	**There has been much interest in driving the ballistic (MOSS) screens commercially for use by Maintenance Delivery Electricity (MDE), and indeed other utility partners.** **One critical point of the testing program that was not looked at was the actual fail point (if possible to reach) by nature of proximity.** **It is important that we study the chosen design for very close proximity screening, whereby the screens are no further away than 5m and take the full force of a failing CT. To this end a 275kv FMJL CT was taken to RADNOR along with 4m high screens in order to study a scenario very close to reality.** **It has also been raised that at the same time, it would be advantageous to put some study into the actual properties of our current palliative screening (Scaffolding and Boards) along side the GRP ballistic screen. This will enable the properties of both systems to be compared side by side.** **Display screens are to be taken and permanently displayed at Eakring Learning Centre as part of an awareness campaign which aims to raise the profile of the R&D program and the availability of these screens to MDE.** **Testing for close proximity of both scaffolding and MOSS screens is being planned in for August at the range.** **In the one testing schedule, several components will be studied including the screens resistance to ejected molten metal.** **Once the close proximity study is completed and we have quantitative data concerning MOSS screens and Scaffolding, all focus will be on driving a scheme to supply significant quantities to MDE.**			
Collaborative partners				
R&D provider	**Doble PT, RADNOR, Redman Composites**			

Project title	**High Level Indoor Isolator Access**		
Project Engineer	**Dave Turnill**		
Description of project	**A standardisation of safe working practice and adoption of an interim solution utilising approved methods of accessing both fixed and moving contacts of high level indoor isolators for maintenance activities.** **An interim solution will reduce the level of exposure to the danger from working at height with the development of a bespoke access podium which can be readily manoeuvred around the existing safe working area.** **A Final Solutions will remove and replace the current inadequate fixed handrail system and working floor area which has very restrictive access and implement an engineering solution it will necessitate maintaining safety distances. The solution will have to be a readily applied interlocked safety barrier. When the safety barrier is not in use it can be retracted/withdrawn/removed/lowered to be outside safety distances prior to it being returned to service. It will further reduce the level of exposure of maintenance delivery electricity (MDE) staff to the dangers of working at height.** **It is envisaged that the interim solution will be adopted in the short term and can be developed and finalised in the next 12 months. The long term objective of a final solution to negate the requirement for the interim solutions will take possibly up to 10 years to implement due to system constraints and the restricted access which this allows MDE.**		
Expenditure for financial year	**Internal £5k External £34k Total £39K**	**Expenditure in previous (IFI) financial years**	**Internal £18k External £28k Total £46k**
Total project costs (collaborative + external + [company])	**£84k**	**Projected 2013/14 costs for National Grid**	**£33k**
Technological area and/or issue addressed by project	**Within National Grid we have 10 substations on the system which are of an indoor design with both main and reserve busbar isolators located above the circuit breakers on the second floor (Photo 1).** **Historically MDE staff have maintained the rotating centre post isolators which have 6 fixed contacts and 6 moving contacts either by accessing from a ladder or climbing the insulator stack with the assistance of a pole strap. These practices have now been outlawed due to legislation changes and policy changes but no replacement method of accessing the equipment to carry out maintenance has been highlighted or developed to allow MDE maintenance to continue.** **However in the original design all the 9 insulator stacks were not located within the safe working and hand railed area (photo2). The picture is of a Main Bar isolator and it can be seen that both fixed contacts are outside the safe working area. The photograph was taken at Ferrybridge which was the scene of a major incident in the early 1990s. A MDE fitter was accessing the moving contact to carry out maintenance from a ladder**		

<table>
<tr>
<td></td>
<td colspan="4">stood up against the moving arm of the isolator. Unfortunately the isolator arm moved away and as a consequence he fell on the breaker floor some 8m below severely injuring himself. Also a near miss at Lister Drive in October 2010 was logged after a hand rail gave way, no one was injured but the potential of an incident remain very high.

 
It is proposed to extend the safe working area to encompass all 9 stacks which make up the isolator. This will however necessitate the need to develop a bespoke hand rail mechanism. In Photo 1 there is a need to maintain the physical separation between the MBB Isolator on the right and the RBB isolator on the left. At this point the hand rail will be required to be a bespoke engineered solution for the following reasons.
To maintain the safety distance when in service.
To maintain the physical separation between bays.
To not interfere with access or reduce the access capability to the adjacent bay
To provide adequate fall protection when applied and in position
To provide interlocking with isolations and earthing so it cannot be returned to service with the hand rail in its deployed position.</td>
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<tr>
<td rowspan="2">Type(s) of innovation involved</td>
<td rowspan="2">Incremental</td>
<td>Project Benefits Rating</td>
<td>Project Residual Risk</td>
<td>Overall Project Score</td>
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<tr>
<td>9</td>
<td>-4</td>
<td>13</td>
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<td>Expected benefits of project</td>
<td colspan="4">This project will provide a package of solutions and systems which are user friendly, very effective and will ensure our MDE maintenance staff have the best working environment to eliminate their exposure to the dangers of working at height. The final removal of this health, safety and restricted access issue will have other benefits such as cost savings gained from reduced use of scaffold, tower hire and platform hire, it will reduce the amount of time taken to set up and complete the maintenance.
.
It is worth noting that the current annual costs of scaffolding, tower and platform hire will cease once the safe working area and hand rail has been extended to encompass all 9 isolator stacks.</td>
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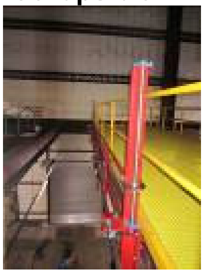
Expected timescale of project	**3 years**	**Duration of benefit once achieved**	**5 years**
Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£27k**
Potential for achieving expected benefits	**Interim Solution** **Having provisionally investigated the interim solution, it appears there is nothing on the open market that fulfils our requirements for an access podium suitably to allow ready access to the 9 stacks. This project will utilise modern materials to enable a lightweight platform to be designed and manufactured which would be suitable for accessing the top of the RCP Isolator tower. Initial investigations indicate a very high chance of success with this project.** **Final Solutions.** **Having provisionally investigated the final solution it appears there is nothing on the open market that suitably fulfils our requirements. There would however be extensive development in guaranteeing the final solution is both suitable and appropriate to MDE's needs. Initial investigations indicate a high chance of success with this project.**		
Project progress **[Year to End of March 2013]**	**Currently awaiting responses from 'hot-stick' manufacturers in order to use them as permanent hand rails. This was due to the fact that the projected costs for the installation of the retractable hand rails were very high.** **Also the development of the access podiums had limited success due to the manufacturer not being able to produce bespoke designs.** **Interim Solution** **Bratts Ladders have developed a bespoke podium for accessing the isolator fixed and moving contacts. This has been trialled in the field and following further recommendations resulting form the field trials the design has now been once more modified. The Podiums are currently awaiting suitable outages so they can be field trialled once more.** **Final Solution.** **Following a successful stage 1 of the Development Plan, which was to bring the work area up to current working at height standards, this then led into Stage 2 which was to design, manufacture and install both a collapsible and tilting hand railing systems.**		

Tilting **Collapsible**



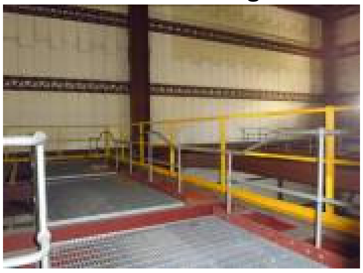
Stage 2 was completed and both systems were installed at Ferrybridge. The installation proved very successful and both the Tilting and Collapsible Hand Railings designed provided a robust and suitable solution. However the complexity of the installation phase was grossly underestimated and as a direct result the installation costs of both systems proved far more expensive than estimated. This has had a knock on effect whereby the unit price of each solution has risen to a level where it has become financially unviable for this solution to be pursued any further unless significant costs can be removed from the manufacturing and installation process. This development solution will now be "parked" until a suitable alternative solution can be developed. It is now proposed that the team investigates other ideas in an attempt to provide a more cost effective solution.

The first idea to be investigated will be the concept of installing fully insulated hand railing which will attach to the top of the existing structure and remain permanently in situ. The project will be progresses in order to come up with a suitable solution which will make the work areas, where the isolators reside, conform to the requirements of working at height legislation.

Interim Solution
Bratts Ladders have provided suitable drawings for a prototype to be built. Preliminary drawings proved unsuitable and were returned with comments. After protracted delays, the drawings were accepted.
A prototype podium has been built and inspected at Bratts Ladders but it was recommended that further modifications would be required to the securing/locking device before it will be sent for field trials.

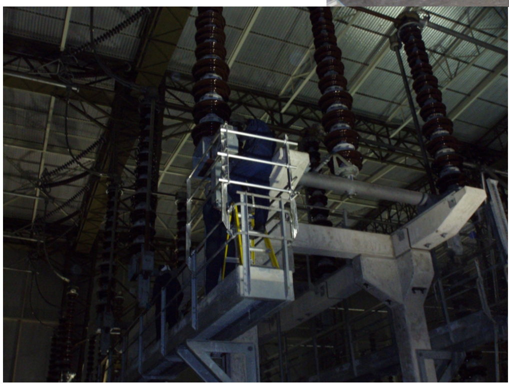
Final Solutions.
Retractable Handrail: A meeting is to be set up with Ferrybridge, Precision Engineering and Parkway to discuss access to a spare bay with a view to setting up a test bay area.

The Stage 1 Bay Refurbishment at Ferrybridge is now complete. The handrails and flooring have now been replaced. This has been done to provide a safe working area during the construction phase of the retractable handrails

	We are now awaiting site meeting with Precision Engineering prior to the start of Stage 2. **Before**  **During**  **After** 
Collaborative partners	
R&D provider	**Planet Platforms, Bratts Ladders, Parkway Sheetmetal**

Project title	Fixed Maintenance Earth (FME) - Development of Handling Techniques and Tools		
Project Engineer	Matthew Grey		
Description of project	This project has several objectives relating to three issues surrounding the continued use of fixed maintenance earths (FMEs) by National Grid staff. These are: To implement and standardise the Manual Handling and Working at Height technique to transport/transfer FMEs from ground level onto high level working gantries. To develop further a FME Access Platform for FME Maintenance To develop further an Extended Hand Railing for FME Maintenance. All 3 key objectives are an effort to reduce the manual handling and working at height requirements for Maintenance Delivery Electricity (MDE) substation staff to complete required safety switching & maintenance activities in a manner which will not place unnecessary stresses on their bodies and thus reduce occupational health issues.		
Expenditure for financial year	Internal £7K External £0K Total £7K	Expenditure in previous (IFI) financial years	Internal £15k External £9K Total £24K
Total project costs (collaborative + external + [company])	£30K	Projected 2013/14 costs for National Grid	£0K
Technological area and/or issue addressed by project	Historically the Reyrolle FME has always been considered the most onerous and difficult type of Fixed Maintenance Earth to apply. This is due mainly to their inherent design, manual handling and working at height issues surrounding the application of FMEs. The FME is a 3 section portable earthing arm weighing 45kg in total, with 1 set of 3 primary earths being made up of 9 sections in total. Many National Grid substations were designed and constructed in an era where health and safety considerations for maintenance staff were less of a concern than they are today. As a result the location of earthing points can be up to 10m above ground level and the ability to apply and maintain FMEs safely in these conditions is extremely restricted. One of the major issues is transporting the FME sections from ground to the required height before application. Historically the methods utilized to perform this task vary from area to area, most of which no longer conform to current legislation. Some sites have tried to utilize the Mobile elevating work platforms (MEWPs) available from Nationwide to lift using home made attachments with limited success. Nationwide now have in their extended range the facility to provide a Sky Rak Boom, though this will require a bespoke fitting to suit our needs specifically. It is intended that this technique will be further developed and trialled to suit National Grid requirements.		

Sky RAK Boom **FME Access Platform**
FME Extended Handrail

Another major issue is the maintenance of FMEs at height. This has previously involved utilizing a step ladder while already at height. The development and trialling of an access platform and extended handrail system as pictured above should reduce the inherent risk of these maintenance activities.

Type(s) of innovation involved	**Incremental**	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		9	**-6**	**15**
Expected benefits of project	**This project will provide a system which is user friendly, very effective and will ensure we give our maintenance delivery engineering (MDE) maintenance persons the best working environment to eliminate the risk to their health. The long term occupational health benefits to the company will mean less man hours lost due to lower back and muscular injuries sustained during the routine maintenance activities. The reduction in long term occupational health issues is unquantifiable but the reduction of injuries we cause to our staff undertaking their routine duties cannot be underestimated.**			
Expected timescale of project	**3 year**	**Duration of benefit once achieved**	**5 years**	
Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**-£20k**	

Potential for achieving expected benefits	Although there is currently nothing on the open market which will fulfil our requirements, it is envisaged that there is a high possibility of success with this project if we work in partnership with Nationwide. It is expected that the basic design FME Sky Rak Boom lifting device rolled into the provision of single Nationwide MEWP, hence it is also expected that this project will have a high possibility of success. A prototype Access platform and hand rail has been constructed therefore making a MKII model incorporating comments and engineering developments would see this project move towards a successful conclusion.
Project progress [Year to End of March 2013]	Drawings were received from The Millward Project and sent out to site after they reviewed the previous designs. We are awaiting comments from site regarding the suitability of this new design prior to progressing this any further. April 2012- This project has proven very difficult to implement due to the complexity of the solution required on all parts of the project. The project has had some success with the SkyRakBoom which has been trialled and is very close to sanction for use with lifting the FME's. From the original project proposal items 1 & 2 look to be drawing to a successful conclusion. Project 3 - A prototype Access Platform and Hand Rail has proved difficult to find a suitable solution there has been limited success to date due to the limitations imposed on by the working area and working at height legalisation. Several prototypes have been designed but implementation on site has been unsuccessful. Following meetings at Pentir with ENI, Safety, MDE and Delivery Support Development Engineer in conjunction with The Millward Partnership. It has been confirmed that the original design is unsuitable and an agreed proposal is to be explored with a view to engineering out the short falls of the original design. The project will now revisit past success in an attempt to move the project forward by utilising all parts that has been successful and designing out any that have been unsuccessful. A Change Control was submitted with this Annual Report submission. March 2011 - Nationwide FME SkyRak Boom Unfortunately this project has stalled to Nationwide's lack of input into coming up with a prototype design. March 2011 - Prototype Access Platform slow progress has been made on this project due to Bratts Ladders lack of input in producing conceptual drawings. Though we are now awaiting a trial at Wylfa of a MKI prototype staging with integral handrails. MKII Prototype  MKI Prototype  

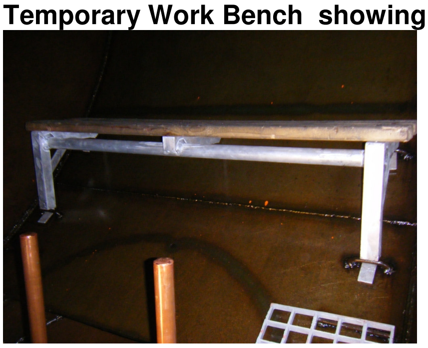
	The original platform and external handrail concept was not considered a viable option due to the very poor condition of handrails at other substations in the country. It was therefore decide to go for a platform with integral handrails.
Collaborative partners	
R&D provider	**Millward Partnership Nationwide Platforms, Bratts Ladders Parkway Sheetmetal.**

Project title	JW420 - developing improved maintenance tools and techniques		
Project Engineer	Matthew Grey		
Description of project	The aim of this project is to provide as safe a working environment as possible for maintenance activities carried out on JW420 bulk oil circuit breakers (OCBs). The aim is to ensure the improved maintenance tools and techniques are used across Maintenance Delivery Electricity (MDE) by further developing solutions and techniques that have been partially developed and used locally in the past. These include developing the following: 2 light weight access benches A light weight rear access working platform connecting the 2 benches to allow 3 side access to the primary contacts A temporary 1kg step arrangement to allow access to the top damper plug Temporary flooring for Basic Maintenance Temporary platforms for major maintenance Turbulator Manual Handling Device. Primary contact closing gag.		
Expenditure for financial year	Internal £11k External £10k Total £21k	Expenditure in previous (IFI) financial years	Internal £15k External £19k Total £33k
Total project costs (collaborative + external + [company])	£64k	Projected 2013/14 costs for National Grid	£10k
Technological area and/or issue addressed by project	The JW420 Bulk Oil Circuit Breaker is likely to see a number of years of further service beyond its original design life due to its Anticipated Asset Life being increased from 45 to 55 years by Asset Policy. There are currently 130 JW420 circuit breakers installed on the system. The JW420 design was originally installed in the 1960s and as such was not designed with modern health and safety requirements in mind. If National Grid intends to maximise the life of these assets then ensuring that they can be maintained in the safest way possible is paramount. There are several issues relating to JW420 maintenance that will be addressed by this project. They are detailed below: JW420 Tank Temporary Flooring Assembly and Working Access Platforms There are a number of maintenance activities that utilize the installation of a temporary access/flooring within the tanks of the JW 420/421 Bulk Oil Circuit Breakers. Once the CB tanks are emptied of oil then access within the contact tank is required to: Fit the slow closing damper plug which is located in the top of the tank on the mechanism approx 3m from floor level Carry out internal bushing oil samples. The sample point is located in the top of the tank on the mechanism approx 3m from floor level Carry out maintenance to the main CB contacts and assembly. The benches currently being utilized were built and supplied on the original build back in the 1960s. Each bench weighs approx 15kg and each tank takes 2 benches. Each bench has to be manually handled through the 600mm port hole on the side of the tank which can be seen below. This is currently the only bespoke aid supplied to give a working platform within. Each area then devises its own solution to access into top of the tank to fit the damper plug, many of which are not best practice. Due to the environment within the tank all surfaces are coated in a film of oil and therefore very slippery. In the last picture one team have devised temporary flooring in an effort to reduce risk of a slip hazard.		

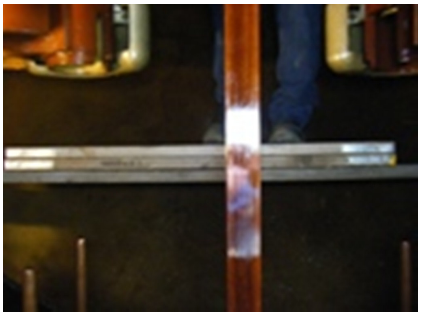
JW 420 Bulk Oil CB Tanks

600mm Entrance Port hole showing primary contact

Temporary Work Bench showing Flooring



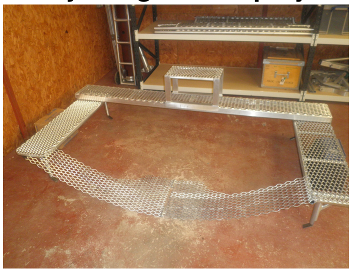
Temporary Access Platform



JW420 Turbulator Handling Device

In the early 90s, during extensive system disturbances, the JW420 OCBs at Brinsworth cleared many faults. As a consequence all breakers were entered and the primary fixed contact replaced. This involves the removal of 6 Turbulators. Due to a high number of removals, the local team developed a manual handling device to assist in the removal of the Turbulators. The original which was developed weighed 12kg; this added to the 53kg of the Turbulator gives a combined weight of 65kg. A new redesigned and rationalised handling device would weigh in at around 3 to 4kg therefore reducing the overall weight down to 56 - 57kg. Future development to reduce the profile and structure has also been identified.

	 JW420 Spring Closing Gag. In order to stop the CB opening when it is in the closed position a gag is fitted under the primary contact cradle. The gag prevents the CB from inadvertently opening when men are at work inside the CB.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		6	-5	11
Expected benefits of project	Health & Safety - Working at Height, Slips, Trips & Falls. Manual Handling– the provision of lightweight benches weight reduced from 15kg to 4kg, provision of a bespoke engineered rear access working platform weighing 8kg, provision of a bespoke engineered temporary flooring, a 1kg step and 4kg Turbulator manual handling device will provide a pieces of equipment which will reduce the effect of working at heights, the effort required for manual handling and reduce the likelihood of slips, trips and falls, all these risks will be reduced to an absolute minimum. The long / short term health benefits to the company will mean less man hours lost due to lower back and muscular injuries sustained during routine maintenance activities. The reduction in long term occupational health issues is unquantifiable but the reduction of injuries to our staff undertaking their routine duties cannot be underestimated.			
Expected timescale of project	2 years	Duration of benefit once achieved	5 years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£27k	
Potential for achieving expected benefits	The chances of delivering the project's 6 aspects to a satisfactory conclusion are very high. 1 Light weight access benches - High 2 A light weight rear access working platform connecting the 2 benches to allow 3 side access to the primary contacts - High A Temporary 1kg step arrangement to allow access to the top damper plug – High Port hole entrance temporary flooring. - High Turbulator Manual Handling Device. - High Primary contact closing gag - Medium			

Project progress [Year to End of March 2013]	Issues continue surrounding the supplier of the lightweight access bench, rear access working bench, temporary step and porthole entrance flooring. All these items have now been sent to Rossendale Lifting Group, who are in the process of back engineering the design in order to replicate it and roll it out. 2011 – 2012 After final minor modifications to the equipment, successful field trials followed to prove this redesign. This part of the project is due imminently for presentation for sanction to Senior MDE Management. A scheme has been raised to provide MDE staff with the device for use in the field. The cost of implementing the solution throughout MDE is holding this project back from full roll out throughout MDE. JW420 Turbulator Handling Device Following final minor modifications to the equipment and successful field trials followed to prove this redesign. Following this a scheme will be raised and sets purchased to provide MDE staff with the device for use in the field. JW420 Spring closing Gag. This period has seen significant progress in the development of the JW420 Spring Closer Gag associated with this project. The project has moved swiftly with designs moving to prototypes which have then been modified in line with comments from MDE Maintenance Staff made during field trials of the apparatus A scheme will be raised to provide MDE staff with the device for use in the field. 2010 - 2011 This period has seen significant progress in the development of the benches and stagings associated with this project. The original designs have been modified in line with comments from MDE Maintenance Staff made during field trials of the apparatus. The benches and stagings have now had 4 field trials and each has proved very successful.. The final design has now also been proof load tested to a satisfactory safety margin. This project is now reaching its conclusion.   JW420 Turbulator Handling Device. The Turbulator handling device has now been for field trials and proved very successful; compared to its predecessor. This project is now reaching its conclusion. Before After   JW420 Spring closing Gag. This spring closer gag for the JW420 as mentioned in the maintenance

	work specification is an urban myth and will have to be developed from first principles. A JW420 Trip latch mech is being sought to assist in the design. A spring closer gag for the OW410 has been identified, this is the 132kV version of the 275kV JW420. Through development of the OW410 spring closer gag a solution can be developed for JW420. This project is still in its infancy. 
Collaborative partners	
R&D provider	Rossendale Group, John Andrews Precision Engineering

Project title	Air Receiver Inspection Cover Hinge		
Project Engineer	Matthew Grey		
Description of project	The project will deliver a safe method of manual handling the elliptical door hatch which provides inspection access to both the Circuit Breaker (CB), Local Air Receiver (LAR) and substation air system Main Air Receivers (MAR). Both designs of air receiver have an elliptical inspection hatch that has to be manually handled to open and remove during routine WSE (Written Scheme of Examination) Inspection and maintenance activities. The key objective is to safeguard the current workforce. This will be delivered in an effort to reduce the manual handling requirements for Maintenance Delivery Electricity (MDE) Substation staff to complete WSE inspection & maintenance activities in a manner which will not place unnecessary stresses on their bodies and thus reduce occupational health issues.		
Expenditure for financial year 11/12	Internal £12k External £19k Total £30k	Expenditure in previous (IFI) financial years	Internal £9k External £21k Total £30k
Total project costs (collaborative + external + [company])	£60k	Projected 2013/14 costs for National Grid	£0k
Technological area and/or issue addressed by project	During the WSE Inspection and maintenance it is necessary to open manually and remove the inspection hatch in a controlled manner. Historically, air blast circuit breakers (ABCBs) and a few specific types of MAR were installed on the system in the 1950s which were designed without an internal hinge. The internal hinge was added on later models to facilitate the safe manual handling of the door. The method utilized by current workforce to open and remove the CB LAR hatch during maintenance never had any bespoke tools provided by the manufacturer to reduce the effect of manual handling. The method employed over the years is to extend to an array of locally derived methods, some of which can be seen in the photographs. All these solutions have proved unsatisfactory solutions in the past, as the practice has resulted in muscular skeletal injuries. There are currently hundreds of CBs with Local Air Receivers on the system without the internal hinge on the inspection cover and		

	approximately between 75 and 100 MARs which would benefit from the development of the Temp Hinge to assist the manual handling of the inspection cover. The usage is dependant on the Written Scheme of Examination under the Pressure Vessels Regulations. If an Air drier is employed to condition the air, it could be either 13 months for a wet air system or 26 months for a dry air system. Therefore the usage could be annually or bi annually.   

Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		4	-4	8

Expected benefits of project	The project will remove unnecessary and undue stress / strain on MDE staff. The long term occupational health benefits to the company will mean less man hours lost due to lower back and muscular injuries sustained during the routine maintenance activities. The reduction in long term occupational health issues is unquantifiable but the reduction of injuries caused to our staff undertaking their routine duties cannot be underestimated.

Expected timescale of project	1 Year	Duration of benefit once achieved	5 Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£24k

Potential for achieving expected benefits	Although there is currently nothing on the open market which will fulfil our requirement, it is envisaged that there is a high possibility of success with this project. It is expected that the basic design of the Air receiver Temp Hinge can be further developed into a successful tool which will assist MDE staff to carry out their maintenance safely, hence it is also expected that this project will have a high possibility of success.
Project progress [Year to End of March 2013]	We are awaiting a training course to be developed by Learning and Development at Eakring before the delivery of both the units and the training to the respective substations is completed. A document detailing the standard of paintwork on the MAR, to which the magnets are applied, is to be produced to ensure the surface is at an

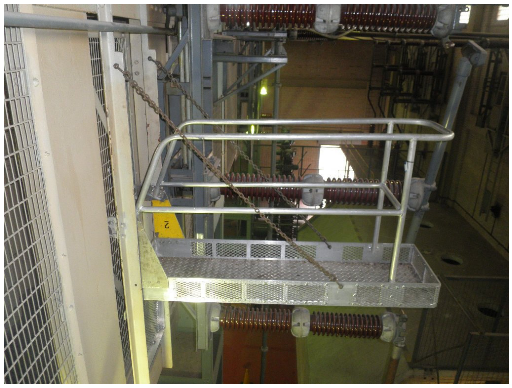
	acceptable standard prior to initial application. **2012 progress: The Air Receiver Project can be further broken down to** **1.Main Air Receiver and** **2.Local Air Receiver** **The MAR project has made significant progress this year following the design and development of an inspection cover handling device.** **This has been extensively tested in the field by MDE staff and has proved very successful following a few minor modifications following recommendations from the field. The use of this device has been approved for use by VELOSI.** **It is expected the project will be sanctioned an approved for use on the system this fiscal year.**  **The Local Air Receiver project is lagging behind and will be developed utilising many of the lessons learned form the MAR device.**  **A prototype has been designed developed manufactured it will go through extensive trails and development in the field this summer.**
Collaborative partners	
R&D provider	**Precision Engineering Pontefract**

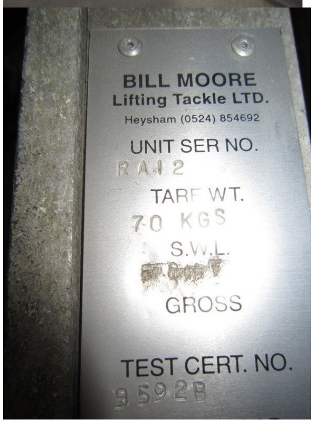
Project title	Portable Earthing Trailer			
Project Engineer	**Matthew Grey**			
Description of project	**A machine to enable the installation / removal of substation portable earths to be completed in a controlled and safe manner. There are serious manual handling issues with installing portable primary earths within substations, this machine will look to address these issues by providing a suitable mechanical aid.**			
Expenditure for financial year	Internal £17k External £120k **Total £137k**	**Expenditure in previous (IFI) financial years**	**Internal £50k** **External £181k** Total £231k	
Total project costs (collaborative + external + [company])	£368k	**Projected 2013/14 costs for national Grid**	**£38k**	
Technological area and/or issue addressed by project	**Health and Safety**			
Type(s) of innovation involved	Significant	**Project Benefits Rating**	**Project Residual Risk**	Overall Project Score
		11	-4	**15**
Expected benefits of project	**This will aim to produce a machine which is both easily transportable within the substations and provides a manual aid to enable the portable earths to be both installed and removed in a safe and efficient manner. The main business benefit is both the immediate and long term welfare of the substation staff carrying out the task. In 2009/10 there was a fatality directly attributed to the removal of portable earthing.**			
Expected timescale of project	6 years	**Duration of benefit once achieved**	**5 Years**	
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	**£170k**	
Potential for achieving expected benefits	**The initial prototype is being designed to enable the concept to be proven. Once the prototype is available and trials are completed a more definite idea of the success and achievement of benefits will be available.**			

Project progress [Year to End of March 2013]	The portable earthing trailer (PET) is currently at Aldercote with a 3m extension fitted that accommodates the gimbal. It requires trialling in order to understand the feasibility of applying portable primary earths at a height of 15m. Gold Consult has now been wound up, Aldercote will have full control of the development of the MK2 PET. **Progress to 2012:** **2007 – 2009 The investigation and evaluation into the possible solutions was completed. A design brief was established and a consultant appointed to progress the design brief to a practical design.** **2009 – 2010 The design of the prototype was progressed. The design was viewed by a number of substation staff with positive feedback. Prototype build initiated, some delays were identified due to concerns regarding the estimated build costs. The initial build is being completed to enable the concept to be proven by field trials, this was understood and the build was re-started. The prototype is expected to be complete by June 2010 at which point the concept trials will be completed.** **2010 – 2011 The concept trails have been completed and the product has been proven to work successfully. Further work may be needed to assess if the initial build costs can be reduced to build an economically viable production product.** **The benefits of this project are reduced manual handling and also increased safety due to up to three earths being applied during an earthing procedure.**   **2011 2012 Although the proven concept has not moved forward in the form of a MKII version we have made considerable progress this year with the transition from concept to a fully functional working primary earthing device. Following the approval of the concept from Maintenance Delivery Electricity (MDE) Senior Management and a desire to move the project forward the PET has been demonstrated to a wide audience of Field Staff in order to gain feedback and come up with a consensus of requirements for a MKII version of the PET.** **We have now engaged Aldercote who specialise in insulated booms and bespoke mini lifting equipment to assist design and build the project.**

	Aldercote and Gold Consult are now taking all the design comments from the demonstration and are designing a MKII PET **The MKI PET has now been trialled extensively on live substations with very positive reports from field staff and suggestions to be incorporated into the future development.**
Collaborative partners	
R&D provider	**Aldercote**

Project title	Bascules and Safety Gate Accessories		
Project Engineer	**Matthew Grey**		
Description of project	**This project will deliver:** **Lightweight Bascule – a lightweight bascule which will allow Maintenance Delivery Electricity (MDE) field Staff to complete the routine maintenance activities when the current bascule is unsuitable.** **Bascule Safety Gate – a lightweight Earthing Safety Gate designed to be deployed during earthing operations.**		
Expenditure for financial year 11/12	Internal £6k External £7k **Total £12k**	**Expenditure in previous (IFI) financial years**	**Internal £10k** **External £21k** Total £30k
Total project costs (collaborative + external + [company])	£42k	**Projected 2013/14 costs for national Grid**	**£13k**
Technological area and/or issue addressed by project	**Lightweight Bascule – there are a number of maintenance activities for which the current bascule is not best practice. The access/egress to some of the 132kv Isolators in the Hall type substation is strictly limited and the equipment needs to be carried manually into the bay area and physically deployed. The current conductor trolleys weigh between 43kg and 75kg, dependant on the manufacturer, and the identified deployment of the current bascules have significant manual handling issues. The lightweight bascule will be designed to have a total weight of less than 25kg which will ensure manual handling issues are kept to an absolute minimum.** **Bascule Earthing Safety Gate – The project will provide the provision of a bespoke lightweight safety gate which will be designed for use during maintenance earthing activities. Currently MDE staff are exposed to the dangers of working at height every time they apply Portable Primary Earths during maintenance activities.** **On the system there are 17 substations of this design which utilise the deployment of bascules to facilitate maintenance activities. Within each substation there are on average 6 bascules per site dependant on the number of sections. We therefore have approximately over 100 bascules on the system. The bascules are only deployed when we carry out isolator maintenance on the reserve and main bar isolators. The maintenance frequency of an isolator is 3 yearly, so dependant on the number of circuits within the sub station they could be utilised between 2 and 4 times per year.**		





Earthing Safety Gate **Deployed Bascule**

Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	Overall Project Score
		6	-3	**9**

Expected benefits of project	**Health & Safety – the provision of a lightweight bascule will provide a piece of equipment which will reduce the manual handling risk to an absolute minimum.** **This project will provide a system which is user friendly, environmentally friendly, very effective and will ensure our Field Staff have the best working environment to eliminate risk to their health. The long term occupational health benefits to the company will mean less man hours lost due to lower back and muscular injuries sustained during the routine maintenance activities. The reduction in long term occupational health issues is unquantifiable but the reduction of injuries caused to staff undertaking their routine duties cannot be underestimated.** **As well as this equipment being developed for the benefit of National Grid it is anticipated that due to the location of the Hall type subs DNOs will also utilise the bespoke equipment provided.** **By providing the new light weight bascule with a captivated chain system the inspection regime can be reduced to a pre use inspection reducing the costs of 3rd Party inspections.**

Expected timescale of project	1 Year	**Duration of benefit once achieved**	**5 Years**
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	**-£69k**
Potential for achieving expected benefits	**Although there is currently nothing on the open market which will fulfil our requirement it is envisaged that there is a very high possibility of success with this project.**		
Project progress [Year to End of March 2013]	Due to issues surrounding the delivery of the Lightweight Bascule, the project has now been sent to Rossendale Group for back engineering. We are currently awaiting a suitable outage in order for structural engineers to ascertain the loadings on the substation structures etc. Field trials will begin again, once the designers are happy with the loading calculations. **2012 Progress:** **This project made significant progress this year. The new lightweight bascule has been designed developed and manufactured using modern materials and techniques.** **The development has reduced the weight of the bascule from an original approximate weight of between 48kgs to 72kg, down to 24kg.** **The lightweight bascule has been trialled on site at Kingsnorth, redeveloped and re-trialled. Following these trials, it is now necessary to trial the Bascules extensively in the field this summer to gather feedback from field staff prior to presenting this project for sanction.** **The Bascule Safety Gate has now moved forward following design and manufacture this is currently being trialled by MDE field staff and following any redesign work which may be required.**			
Collaborative partners			
R&D provider	**Rossendale Group, Parkway Sheetmetal**		

Project title	Fault Current Distribution in new type of EHV cables			
Project Engineer	Ertugrul Partal			
Description of project	This project aims to derive and calculate the IGR (ground current return) for faults on cross linked polyethylene (XLPE) cable. These derivations can then be utilised to calculate cable factor for different XLPE cable. These cable factors are then to be integrated into Digslient to enable fault current calculations to be carried out semi autonomously.			
Expenditure for financial year 11/12	Internal £5k External £34k Total £39k	Expenditure in previous (IFI) financial years	Internal £13k External £26k Total £39k	
Total project costs (collaborative + external + [company])	£78k	Projected 2013/14 costs for National Grid	£0k	
Technological area and/or issue addressed by project	Although oil filled cables have well-established IGR and cable factors are set out in ER S34 (A guide for Assessing the Rise of Earth Potential at Substation Sites), XLPE cables have had no such study conducted on them. It is vital to understand the electrical properties of the cable sheath in returning some of the earth fault current as this is a key factor in the IGR. In order to analyse new types of XLPE cables, it is necessary to calculate cable parameters to a high degree of accuracy by software packages, numerical methods and formulae. This allows the effect of important variables upon ground return current (IGR) to be calculated. At present time specialist contractors are utilised to calculate the IGR for any cable run. This project aims to codify this knowledge and integrate this into Digslient so IGR for faults can be calculated as a standard procedure.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		7	-2	9
Expected benefits of project	At the current time no XLPE cables are being laid due to the inability to calculate the IGR, this is resulting in a delay for load and non-load related connections. The ability to calculate IGR for XPLE will remove one of the potential delays that a new connection may face. IGR in XLPE cables accounts for 5% of the workload however, a typical single calculation set could take an experienced engineer about 1 .5 months once all the data is obtained. Creating this tool will enable IGR calculations to be completed in a week rather than 1.5 months, in addition a less senior engineer can complete the calculations. This tool should result in a saving of 5 working weeks per calculation. National Grid currently experiences 4 of these per year however this is set to rise resulting in a saving of £33k per year. In addition, the project will produce a standardised auditable process for XLPE cable IGR calculations.			
Expected timescale of project	1 year	Duration of benefit once achieved	5 year	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£10k	
Potential for achieving expected benefits	The likelihood of success of this project is high given the areas of expertise from the chosen supplier. Once these cable factors have been calculated they could have potential impacts on European standards.			

Project progress [Year to End of March 2013]	**The final presentation by Prof Benato has been delivered at National Grid House on 27th April 2012. The final report and Matlab tool have also been handed to National Grid.** **This R&D work has been completed on time (30 April 2012) as agreed.** **This software tool will be used internally for new types of cables and overhead lines (OHLs) for 'specific' applications.**
Collaborative partners	
R&D provider	**University of Padova-Italy**

Project title	Exported potentials and profiles around earth electrodes and opposite-side injection for large-area earthing systems		
Project Engineer	Dongsheng Guo		
Description of project	The project proposal is divided into five areas of investigation; Prediction of ground surface exported potentials and potential fall-off in the vicinity of earth electrodes: • Previous work has demonstrated that exported potentials can be measured fairly accurately using the developed techniques. It is proposed that these tests are carried out at Dinorwig and at Llanrumney test sites. Investigation into scalability of low-current injection testing: • Previous tests have shown that there is a current dependence of the measured earth impedance in the range 10mA to 5A. In this project, it is proposed to explore and understand these changes over a wider range of current magnitudes including the high current impulse test. Investigation of non-linear effects of earth impedance at low-current magnitude and associated polarisation: • These laboratory-based investigations will be focussed on clarifying the observed dependence of earth impedance on current magnitude. In particular, it will explore the physical phenomena involved with this behaviour, e.g. i) polarising effects at the electrode-soil interface and the soil-soil particle interface and ii) other non-linear effects including thermal dependence. Investigation into frequency effects of earth impedance: • An investigation into the frequency effects in earthing system measurements will be undertaken in the laboratory and in the field, to explore further the variability seen from the previous tests and allow a better understanding of the trends. Modelling of earth electrodes accounting for non-linear effects: • Comparison of the test results, obtained from the practical tests described in points 1-4 above, with computer simulations of the electrodes (CDEGS and physical modelling – Finite element and boundary element) will allow a better model and equivalent circuits of earth electrodes to be developed accounting for the non-linear effects.		
Expenditure for financial year	Internal £6k External £73k Total £78k	Expenditure in previous (IFI) financial years	Internal £6k External £92k Total £98k
Total project costs (collaborative + external + [company])	£175k	Projected 2013/14 costs for National Grid	£134k

<table>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">To determine the safety voltages, the extent of hot-zones and exported potentials accurately is crucial in terms of earthing systems design. This will allow developing efficient and reliable mitigation measures.

In addition, current testing methods/instruments operate in the range of 10mA to 5A. Hence, the scalability of the measurement (to high fault current) is yet to be established. Non-linear effects were seen as a function of frequency and current for low magnitudes. Such phenomena will be investigated and the issue of scalability of test results will be addressed. This forms a significant part of this project.

Furthermore, the credibility and accuracy of predictions using simulation software packages has yet to be fully verified experimentally, and this project will address these challenges.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>8</td><td>1</td><td>7</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The following outcomes are expected from the project:

a) Comparison with simulation models will allow refining modelling techniques for such configurations to determine safety voltages and hot zones more accurately in the vicinity of National Grid's installations.

b) The proposed tests will allow confidence building in the low-current measurement systems currently employed for earth impedance testing at National Grid substations and the subsequent extrapolation utilised to evaluate the prospective safety voltages at system fault levels. In this way, a better estimation will be obtained.

c) This work will enhance the understanding of the results obtained from the field tests and will also allow an insight into the main mechanisms involved with seasonal variation of earthing system performance.

d) The outcome of this work will allow a better extrapolation of the measured values of earth impedance at low current magnitudes to those applicable under real system fault levels.

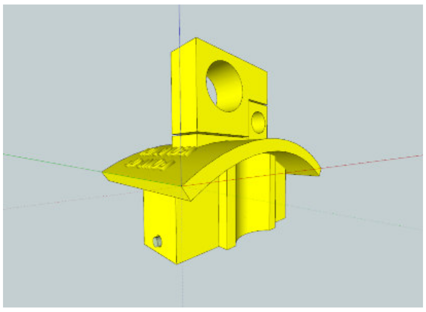
Such outcomes will further allow

• Higher confidence in earthing impedance measurements
• Higher confidence and accuracy in the extension of hot-zones, and in turn,
• More accurate determination of substation footprint and need of mitigation investment.
• Potential savings: There are approximately 30 sites queried each year in regards to hot zone issues. A more accurate simulation tool would enable savings of £2-3k per site if successful. This project should result in a saving of £30 – 60k per year. Depending on the specific site situations, the saving on mitigation (although may not be National Grid's direct responsibility) could be in the range of £100k and also reduce the sites footprint.</td></tr>
<tr><td>Expected timescale of project</td><td>2 years</td><td colspan="2">Duration of benefit once achieved</td><td>5 years</td></tr>
</table>

Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£8K**
Potential for achieving expected benefits	**Potential for achieving benefits is high as Cardiff University have carried out research projects covering some of the above issues with promising preliminary results. Furthermore, they have acquired necessary site facilities and experience. The above challenges will therefore be addressed more efficiently and successfully.** **Furthermore, previous work carried out by the group at Dinorwig power station will be built on to address the most challenging issues of the research project.**		
Project progress [Year to End of March 2013]	**The main project work started in May 2012. However, preliminary work started earlier, with a focus on finalising the previous results and carrying out further detailed simulations. Such results allowed better preparation for the next wave of tests. The results were incorporated in two Journal papers and submitted to IEEE transactions on Power Delivery (under review).** **The new power supply generator has been acquired.** **The Llanrummey test site has been set up for high current injection on test electrodes and a dedicated 200kV high voltage impulse generator has been prepared. Detailed simulations of the new test set up have been carried out and tests are expected to commence in June 2013.** **The Dinorwig test site has been prepared including (i) re-design of the pontoon, (ii) servicing and safety clearance of equipment, (iii) Safety training (National Grid Person, BESC and First Hydro Safety Clearance and safety document acceptance training completed). Preliminary tests are expected in July 2013, following completion of proving tests at Llanrumney.** **The laboratory test cells (2) for investigation of conduction mechanisms have been designed and are under construction. Detailed COMSOL models (engineering simulation models) have been established which were used to inform the design.**		
Collaborative partners			
R&D provider	**Cardiff University**		

Project Title	Artic Fuse and Link Development Project		
Project Engineer	Matthew Grey		
Description of project	The project will deliver 2 key aspects for the health safety and welfare of Field Staff. 1. The elimination of hazardous asbestos associated with this type of fuse and links from the system. 2. The ability to apply a lockable device to the fuse holder for isolation purposes during manual switching and isolation duties.		
Expenditure for financial year	Internal £4k External £20k Total £24k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£41k	Projected 2013/14 costs for National Grid	£17k
Technological area and/or issue addressed by project	1. Hazardous Asbestos The Issue -The Artic fuses and links are a legacy item of equipment that have been on the system since the SuperGrid system was built back in the 1950s. As a direct result from the era in which the SuperGrid system was built, the construction of the fuse and links have embedded asbestos flashguards, which can be seen below. The purpose of the asbestos flashguard on the fuse is to give the fuse holder protection against the very high energy levels which are realised during fault operations.   It is proposed to address this issue by developing a suitable contemporary material as a direct replacement for the asbestos. 2. Lockable Isolation. The issue - Following a senior authorised oerson (SAP) stand-down day a request was submitted to the Development Group to investigate the potential of developing a lockable fuse and link holder in order for us to comply with legislative requirements. This followed a site visit by HSE to a NG substation where he observed our practice of		

not locking fuse holders but simply applying Point Of Isolation (POI) caution tape. This was suggested to be an inadequate precaution and should be addressed as matter of urgency and replaced with a lockable insert to replace the POI caution tape.



The number of Artic fuses and links which remain on the system (as a general guide) could run into 2 thousand. These fuses and links are removed on a regular basis during an outage as they form part of the LV isolations which a SAP has to implement in the course of his duties. The most hazardous time for any person handling these fuse and links is during the insertion and removal when asbestos particulate can become air borne.

Type(s) of innovation involved	Technological Substitution	Project Benefits Rating	Project Residual Risk	Overall Project Score
		22	-9	31
Expected benefits of project	Health & Welfare– The removal of asbestos contained in these devices from the system will have considerable benefits for Field staff health safety and welfare. By removing the asbestos from this device, the hazard is removed from the system and will ensure Field Staff have the best working environment to eliminate the risk to their health. The long term health benefits will mean less man hours lost due to potential ill health. The reduction in long term occupational health issues is unquantifiable but the reduction of injuries is important and beneficial. Safety With the implementation of the lockable fuse and link insert, this will ensure compliance with current standards and reduce the potential for Points of isolation to inadvertently being compromised.			
Expected timescale of project	2 years	Duration of benefit once achieved	8 years	

Probability of success	**90%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£-26684**
Potential for achieving expected benefits	**Although there is currently nothing on the open market which will fulfil our requirements for both solutions, it is envisaged that there is a very high possibility of success with both aspects of this project.**		
Project progress **[Year to End of March 2013]**	**Due to the commercial value surrounding this project and in particular the intellectual property rights, this project has been delayed with delivery expect later this year.**		
Collaborative partners			
R&D provider	**Close Engineering**		

Project Title	Thermo-Mechanical Forces in XLPE Cables		
Project Engineer	David Moorhouse		
Description of project	Through research and testing, this project will allow innovation and the development of current knowledge. This can be input in a technical guidance document relating to the thermo-mechanical behaviour of XLPE cables to assist National Grid cable verification / design assurance activities. This project was initially authorised only for a feasibility study. After successful completion of that study, which was completed as the first part of the project and paid for by SEESA (i.e. Authorised IFI funds were NOT used), the next stage of the project will be the physical testing of cable samples. The tests and methods have been developed by Mott MacDonald and CCI, and will be carried out by the University of Southampton. The responsibilities of the University of Southampton within this project will be: • Design and construction of test rigs presented in CCI report ER459 • Conducting a full suite of tests for thermal expansion, axial stiffness, bending stiffness and torsional stiffness on 2500mm^2 XLPE cables (to be provided by National Grid) • Provision of full technical reports relating to each category of test • Assistance in disseminating key results to manufacturers and industry bodes (Cigre) The tests are essential to the production of the new Thermo-mechanical Behaviour TGN, which will in turn deliver valuable understanding of cable mechanical performance for use in future Design Verification/Assurance activities. The work on 105°C operation will demonstrate whether such operation would be feasible (from a mechanical viewpoint).		
Expenditure for financial year	Internal £4k External £1k Total £5k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£220k	Projected 2013/14 costs for National Grid	£215K
Technological area and/or issue addressed by project	National Grid has a problem understanding the magnitude of thermo-mechanical effects of large cross-section cross linked polyethylene (XLPE) cables. This problem leads to particular difficulties in designing the steel support work where cables meet gas insulated switchgear (GIS) and air insulated switchgear (AIS) terminations. It is currently suspected that they are over engineered. National Grid is presently producing a new Technical Guidance Note (TGN) on the thermo-mechanical design of cable systems. It is essential to the safe operation of any cable circuit that		

	adequate mechanical restraint is provided. This requires the forces exerted by the cable whilst under load be known. Little work has been undertaken worldwide on this issue. This project will study the thermo-mechanical behaviour of 2500mm^2 XLPE cable systems through a series of tests to be performed by the University of Southampton. The design of the tests has been informed by CCI Technical report ER459, alongside discussions at TGN working group meetings. In addition to studying the behaviour of XLPE cables at the standard operating temperature of 90℃, the thermo-mechanical behaviour of such systems at maximum temperatures of 105℃ will also be investigated. This is recognised as a way in which higher emergency ratings may be attained, however consideration must be given as to whether the installations used in the past would be capable of sustaining the increased mechanical forces exerted by the cable if it were to operated in this manner. This will be addressed by researching methods of calculating / measuring the thermo-mechanical forces imposed, and possible methods of eliminating them by physical testing and the use of Finite Element Analyses			
Type(s) of innovation involved	**Incremental**	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		10	**-9**	**19**
Expected benefits of project	**<u>Potential project benefits are:</u>** • Improved clarity for design assurance would optimise cable system and civil designs, as well as costs, whilst improving risk management. • Improved standardisation of calculation methods within the industry, leading to reduced disputes during project implementation. • To define the thermo mechanical requirements of raised operating temperatures. This would allow implementation of increased operation loads. This potentially allows both cost reduction for future installations and cost avoidance of replacing or adding to current installations. • If the research is successful, it would help define the thermo mechanical requirements of raised operating temperatures. This would allow implementation of increased operation loads. This potentially allows both cost reduction for future installations and cost avoidance of replacing or adding to current installations. If the research is not done, and higher loadings cannot be proven as safe then larger conductors or 3 cables per phase maybe necessary. This could lead to 30-40% increase in project costs, over all cable projects. For example:			

	2500mm² copper conductor XLPE cable is approx £400/m. Therefore: 2 cables per phase is £800/m, 3 cables per phase is £1200/m, So on one 1km installation it would cost £400K more to use 3 cables/phase. And this doesn't include the installation costs. • Prevent occurrence of failure, such as that experienced in Auckland, New Zealand, in1998. The city centre was without electricity for 5 weeks, with some businesses estimating that the outage cost them at least NZ$60,000 per week. • The understanding gained though the research could also be used to avoid the loss of a cable circuit due to thermo-mechanical forces. The costs of this type of failure can be in the region of approximately £500k. There are other examples of where thermo mechanical forces have caused a cable to climb out of the trench, lifting the slabs above it. This situation is then very hard to rectify. • The research may also have positive impacts on other research and development projects, as it is consistent with the cable R and D strategy.		
Expected timescale of project	**2 years**	**Duration of benefit once achieved**	**8 years**
Probability of success	**80%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£69200**
Potential for achieving expected benefits	**Success of feasibility study paid for by SEESA suggests testing would be worthwhile, and carries a medium - high level chance of success.**		
Project progress **[Year to End of March 2013]**	**This project has only just started so there is no reported progress to date. The costs on this project are set-up costs.**		
Collaborative partners			
R&D provider	**CCI, Mott Macdonald, University of Southampton**		

Project title	Development of probabilistic risk assessment procedure for earthing systems
Project Engineer	Dongsheng Guo
Description of project	Previous involvement with international earthing committees has resulted in the recognition and acceptance of a probabilistic risk based approach to earthing system design and assessment. The confidence gained from National Grid to support this approach was as a direct result of previous research that reviewed local fault levels and fault clearance times against site earth potential rise seen under fault conditions. This project should account for any benefit from supportable historic clearance protection times and actual system fault current magnitudes. Such detail will allow a more precise risk assessment and a relaxation away from worst-case scenarios. In order to gain most benefit from these previous research findings, the future research will focus on four main areas; Effect of fault current level on probabilistic risk assessment around substations. An interface between the National Grid simplified GB transmission system model, implemented on Power Factory, and the probabilistic earthing risk assessment software developed at Cardiff University (CRAFTS) will be developed. This facility will allow the engineer to assess the level of risk at particular problem sites, by quantifying the effect of fault current variation on risk level. This will require procedures to be developed that compute fault current data for given locations taking into account generation ranking order and load level over an annual cycle. CDEGS earthing software interface: Investigating the probabilistic risk for exported potentials and hot zones. Currently, hot zones and exported potentials prediction using CDEGS software provides National Grid with useful information for assessing impact on third parties. The research in this area will enhance this information by also including the associated risk level corresponding to the hot zones and exported potentials mapped for a given substation location. Application of recently updated CENELEC/IEC standards to the developed Cardiff probabilistic software (CRAFTS) The developed Cardiff software (CRAFTS) uses BS7354 as a working standard. Recent developments in UK and Europe have resulted in a new set of standards that will be shortly adopted as UK standards in the form of British Standard European Norms (BSENs). These will be, therefore, adopted by National Grid and other Energy Network Association (ENA) members. It is proposed to adapt the CRAFTS software to include the new standard recommendations which include, inter alia, the revised safety limit threshold values. Investigation of variability of probabilistic risk at different locations within a substation.

This research will assess whether the currently used approach of checking the safety voltages at the corner of the substations is the most appropriate method. It is expected that the corners of the substations will have higher probability of higher safety voltage levels compared with other locations in the substations. On the other hand, the presence probability at the corners of the substation is expected to be lower than at the other key frequented locations within the substation.

<table>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £6k
External £53k
Total £58k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £11k
External £198k
Total £209k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£256k</td><td>Projected 2013/14 costs for National Grid</td><td>£45k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">The project addresses the issue of safety and risk assessment of earthing systems. It uses a probabilistic risk assessment approach to quantify the risk involved at large substations. The model developed in this project takes into account the detailed configuration of the earthing system and the surrounding area, and it uses historical fault data. The model can be adapted to any set of standard specification and perform the risk assessment accordingly. A friendly software routing is being developed and tested to help engineers implement the model on practical substations.

This will allow aligning practice against recently published safety voltage thresholds and deliver a software tool that will help a) manage National Grid’s risk responsibilities from voltages seen on earth mats within substations under fault conditions and b) manage exported potentials.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>11</td><td>-1</td><td>12</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The four areas above will lead to significant financial benefits due to avoided remedial work on substation earthing systems that would have previously been identified as being of high risk. In 2008 alone three sites were identified where remedial work was not required thus saving between £50k and £100k per site. This procedure will ensure that savings such as this continue to be made routinely in the future.</td></tr>
<tr><td>Expected timescale</td><td colspan="2">3 years</td><td>Duration of benefit</td><td>5 years</td></tr>
</table>

of project		once achieved	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£154k
Potential for achieving expected benefits	Based upon Cardiff University's previous research in this area, and with the change of standards at IEC/CENELEC levels that recognise Risk Assessments within Earthing design and Earthing assessments, the likelihood of success is extremely positive. The research assistant is in post and available for use on this project.		
Project progress [Year to End of March 2013]	Previously, the software Cardiff Risk Assessment for Transmission Systems "CRAFTS" had been updated to include the findings of the original R&D project and changes in the standards at IEC/CENELEC. Success had been seen in: Building an interface between the CRAFTS software and the CDEGS earthing analysis software and implementing a fault clearance time database. Building a steady-state model of the 400kV/275kV UK transmission system in 'NEPLAN' power system design software and calculating the variation in fault current magnitude and its effect on prediction of individual risk. Undertaking limited case studies with CRAFTS using data provided by National Grid and Scottish Power. This last year, the new Research Associate, Mr Al Mansoor Amin, was appointed in July 2012. Detailed computer simulations have been carried out using Power Factory (DigSilent) to determine earth fault current magnitude variation with system demand and fault location along the transmission line. The studies have focussed on three new case studies (Cowbridge, Strathaven (Scottish Power) and Llandinam (Scottish Power)). The network studies have revealed that reduction in earth fault current magnitude is highly dependent on local network and generation configurations. Work is continuing to establish a comprehensive classification of National Grid/Scottish Power substations earth fault current/demand relationship. Probabilistic risk assessment studies have been carried out on Cowbridge and Strathaven and reported in project deliverables. Work is in progress for Llandinam. The CRAFTS software has been developed to embed the Cardiff probabilistic calculation process in MATLAB (previously in a standalone software @RISK). Current work on CRAFTS is concerned with the implementation of varying risk zones (accounting for presence) and defining exclusion zones where there can be no risk of touch voltage.		
Collaborative partners			

R&D provider	**Cardiff University**

Project title	**Alternative Bus Bar Protection Solution**		
Project Engineer	**Simon Pomeroy**		
Description of project	**This project aims to deliver an evaluation and desk top design solution of an alternative digital bus bar solution architecture. This will help formulate a future technical and procurement strategy for bus bar protection, potentially leading to a pilot installation, evaluation and deployment as a replacement (or new) bus bar protection system.**		
Expenditure for financial year	**Internal £34k** **External £6k** **Total £39**	**Expenditure in previous (IFI) financial years**	**Internal £7k** **External £76k** **Total £83k**
Total project costs (collaborative + external + [company])	**£122K**	**Projected 2013/14 costs for National Grid**	**£10K**
Technological area and/or issue addressed by project	**A policy for single Digital Bus Bar Protection has been employed on the National Grid UK Transmission network since 2002 either as a replacement system (for duplicated high impedance schemes) and for all new build double bus bar substations. These systems have a distributed architecture with remote bay units (interfacing to the plant) for each protected circuit with ruggedized cross site fibre connections to a central processing unit. Where a substation has a centralised relay room (e.g. gas insulated substation) layout, the bay units are co-located in a suite of cubicles and connected with a network of fibre patch cords.** **A number of systems and versions have been installed from National Grid's preferred protection suppliers and Alliances over the past 20 years and these have required additional support through contracted post delivery service agreements (PDSAs) to provide field staff with the resources to manage faults and defects. A recent protection policy change also requires a second (hot standby) central processing unit to be deployed (with it own dedicated fibre connections) to manage contingency issues better for central processing unit failures.** **The systems installed to date have proven to be generally reliable; however each system is bespoke to each supplier with a limited technical life, leading to issues with future substation extensions and potentially the need to consider equipment upgrades and early asset replacement of the complete system. This will have major issues on future system access to carry out this work across a complete substation.** **Through work with CIGRE, contacts with other utilities and National Grid US, it has been found that an alternative centralised bus bar protection system may offer greater asset management benefits in the longer term, especially when managed and supported by well trained internal staff.** **This project is desk top evaluation of an alternative bus bar protection design and the interface and application on the UK Transmission system.**		

Type(s) of innovation involved	**Incremental**	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		6	**-2**	**8**

Expected benefits of project	**The output from this project, if successful, will feed into a second stage project to establish options for a pilot installation.** **The benefits will include the following: -** • **Development of Bus Bar Protection Strategy and Policy changes** • **Standardised plant interface and "one off" standard solution** • **CAPEX savings (reduced equipment costs)** • **OPEX savings (train internal staff- reduce PDSA)** • **Extended Asset Life (elimination of short life components e.g. fibres)** • **Reduced System Access for extensions and future replacement**

Expected timescale of project	**2 years**	**Duration of benefit once achieved**	**5 years**
Probability of success	**95%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**-£11k**

Potential for achieving expected benefits	**This project will review designs and products used by other utilities for adoption on the UK Transmission system.** **The likelihood of success is high.**
Project progress [Year to End of March 2013]	**The contract was placed with SEL (Concord) and the design of the Bus Bar Protection Panels received. Following review of the design drawings by end users, some improvements were requested to the design and build. These modifications were implemented, prior to final panel build, inspection and test.** **Maintenance delivery electricity staff have been involved in assessing these designs and gaining familiarity with the SEL Bus Bar Protection solution and its application. They have also helped develop some technical training programmes.** ***The time and effort this year on this project is mostly associated with supplier discussions, and logistical tasks. There has been some test equipment provided, but problems with the Input/Output boards have led to a delay in the project.*** ***This problem is currently being addressed, but may take some time to fix. It is crucial that the test equipment is correctly set up or this may impact heavily on the accuracy of the equipment.*** ***A list of problems within the equipment has been prepared, for example, the panels are too tall. This is just one issue, there have been others identified that are being addressed in discussions with the manufacturers.***
Collaborative	

partners	
R&D provider	SEL

Project Title	Co-ordinated intelligent system protection against frequency collapse in future low inertia networks		
Project Engineer	Mark Osborne		
Description of project	The goal of the proposal is to research and create a new adaptive protection concept that is capable of guarding against frequency collapse in future energy networks incorporating a significant amount of inverter-interfaced energy sources and loads. This concept will be based on synchronized measurement technology and wide area measurements and will be capable of maintaining system frequency stability in future power systems with low and/or variable inertia levels. The project consists of four main Work Packages (WPs): 1. WP1 Modelling of key system components relevant for the future system frequency response. 2. WP2 Dynamic performance and interaction between different network components. 3. WP3 Creation of a co-ordinated protection against frequency collapse in future energy networks. 4. WP4 Validation and Integration. All four WPs are coordinated activities, with the ultimate objective of contributing to the final research result – a new co-ordinated system protection against frequency collapse in future energy networks.		
Expenditure for financial year	Internal £7k External £0k Total £7k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£1,500k	Projected 2013/14 costs for National Grid	£55K
Technological area and/or issue addressed by project	The high penetration of renewable intermittent energy sources will undoubtedly cause the system inertia (stiffness) to vary significantly. Moreover, the trend of connecting generation resources that are interfaced via inverters will cause an unaffordable reduction in system inertia. Any significant fall in the inertia of a system may compromise the operational system security, in the form of angular- and frequency-instability related problems. The main objectives of the work are to establish the compelling requirement to explore and quantify the efficacy of presently-used deterministic under-frequency load shedding schemes in low/variable-inertia systems. It is believed that existing schemes must be replaced by adaptive novel solutions, capable of protecting systems from frequency collapse and minimising load interruptions. Research must be carried out both in the context of transmission systems with large amounts of		

	intermittent energy sources and for distribution systems with massive penetrations of low-voltage inverter-interfaced energy sources, hybrid and electric vehicles and storage units.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		11	-4	15
Expected benefits of project	For society as a whole: • Minimised number of customers' outages and reduced probability of blackouts. • Reduced CO_2 emission and environmental impact of system operation through its ability to incorporate more renewable energy sources. • Enhanced protection of power system. For National Grid and generators: • Reduced costs and improved performance of traditional under-frequency load shedding which will not be fit for purpose in systems with low/variable inertia. • Improved utilisation of existing transmission and generation assets. • Reduced stability margins and more economical exploitation of the system. • Optimised and adaptive low frequency demand control scheme. • A more efficient use of renewable energy resources, classical generation sources and emerging nuclear generation technology. The project will leverage funding in the region of £1.5m for a contribution of approx £300k over 3 years. EPSRC will pay for 3 RAs and industry pays for the Ph.Ds.			
Expected timescale of project	3 years	Duration of benefit once achieved	8 years	
Probability of success	40%	Project NPV = (PV benefits – PV costs) x probability of success	£1,140,000	
Potential for achieving expected benefits	There is a medium to high chance of success. Whilst the scope of the project is large and complex, the three universities have collaborated together successfully on previous projects.			

Project progress **[Year to End of March 2013]**	**This project has been delayed while EPSRC funding has been sought, however National Grid continues to support the proposal.** **In November 2012 the academic partners led by the University of Manchester submitted an EPSRC project proposal to match the above funding received from industrial partners, requesting an additional £1.2M. It is expected that EPSRC will respond by the end of July 2013, when the Consortium will know the final total level of resources available for the project. However, the Consortium plans to start the work in September/October 2013 with the existing funding received by industrial partners.**
Collaborative partners	**EPSRC, SP,SSE, DNOs, Alstom Grid, Arbiter**
R&D provider	**University Consortium – Universities of Manchester, Bath, Strathclyde**

Project title	**Partial discharge monitoring of DC cable (DCPD)**		
Project Engineer	**Greg Tzemis**		
Description of project	**To investigate and develop a method for monitoring partial discharge (PD) activity in mass impregnated (MI) HVDC cable. The outputs will enhance National Grid's understanding of high power HVDC cable and facilitate the development of improved Technical Specifications. The test method developed should be sufficiently effective and efficient to allow its deployment within the constraints of a commercial Type Test programme.**		
Expenditure for financial year 11/12	**Internal £5k** **External £75k** **Total £80k**	**Expenditure in previous (IFI) financial years**	**Internal £0k** **External £0k** **Total £0k**
Total project costs (collaborative + external + [company])	**£14k**	**Projected 2012/13 costs for National Grid**	**£41k**
Technological area and/or issue addressed by project	**National Grid's Technical Specifications require MI cable to be tested to the internationally accepted CIGRE test procedures. As the operating voltages of DC cables increase cable manufacturers are progressively taking the view that the CIGRE test voltages are too severe and unless the test voltage is reduced (particularly during the cooling phase of heat cycling) there is an unacceptably high risk of the cable failing the type test.** **In order to achieve type registration of these cables it will be necessary for National Grid to consider relaxing the test voltage. There is no published basis to justify this reduction and it is difficult to assess the risk of accepting cable systems which cannot meet the CIGRE requirements.** **There is a possible mitigation strategy based on applying condition monitoring techniques during type testing so that the test is not reliant on simple withstand criteria. When a MI HVDC cable fails the heat cycle type test it is likely to be the result of accumulated PD damage. Hence PD monitoring appears to be the most appropriate option to investigate.** **PD detection in DC systems is significantly more difficult that in AC systems because (i) the discharge repetition rate if far lower and (ii) there is no alternating voltage to which the discharge activity is synchronised. It is therefore difficult to distinguish between PD activity and random background noise.** **Recent work at Southampton on PD from AC cable systems indicates that clustering algorithms can be used to distinguish between PD from different sources. It appears feasible to use this technique during DC testing to distinguish between PD from the cable and that from the terminations or external noise sources. The technique relies on analysing the PD signals to measuring the energy content in a number of time and frequency windows. The multi-dimensional results are converted to a pseudo 3-dimensional data set for easier visualisation and automatic classification.** **In addition to developing a procedure to detect and classify DC PD signals**		

	the work will emphasise the need for the technique to be suitable for implementation during DC cable type tests. This requires that PD testing can be done safely in an industrial laboratory without impacting on the smooth running of the type test.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		5	-1	6
Expected benefits of project	The research will provide a more informed test regime, which will give a better understanding of the performance of the cable system. From this National Grid will gain the information needed for a well-managed change in its Technical Specifications. This will increase the number of suppliers that can become type registered without significantly increase the risk of a major system failure. The estimated costs of a failure on a major HVDC submarine link are in excess of £15m due to the timescales to make a cable repair. Having an increased number of qualified suppliers will lead to reduced capital cost and/or delivery timescales on large HVDC projects.			
Expected timescale of project	1 year	Duration of benefit once achieved	5 years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£76k	
Potential for achieving expected benefits	This proposal seeks to build on the successful record of work at the University of Southampton on partial discharge testing of HV cable system; This has including PD testing of long lengths of submarine cable in a factory environment. Initial work suggests that the instrumentation system is capable of acquiring PD data during DC testing. The excellent results of recent work on the use of clustering algorithms to distinguish between multiple PD sources in AC cable gives a good degree of confidence that the project will have successful outcomes.			
Project progress [Year to End of March 2013]	A literature survey of partial discharge testing of DC cable systems has been carried out. This examines: the mechanisms that cause PD under HVDC stressing, options for PD signal detection, the analysis and classification of HVDC PD and the significance of PD in Mass Impregnated (MI) HVDC cable. Some preliminary experiments were carried out to investigate PD signal detection and analysis. These experiments looked at background noise rejection and the influence of ripple superimposed on the HVDC voltage. The classification of HVDC PD signals was examined by comparing positive and negative corona from different point/plane electrode geometries. Analysis of the phase resolved patterns, pulse waveforms and wavelet energy distribution was undertaken. The results suggest that after further optimisation, wavelet energy distribution might be a suitable feature vector for source discrimination within DC systems. Further experiments were carried out using a three-phase paper insulated MI distribution cable as a model cable. A range of DC voltages of either polarity were applied to the cable whist acquiring PD data from two			

	different instrumentation systems in parallel. The first was a conventional system compliant with IEC 60270. The second system was based on a radio frequency current transformer (RFCT) and oscilloscope. This operates with a wider bandwidth and allows the detailed characteristics of individual pulses to be analysed. Both the positive and negative polarity tests appeared to activate two types of PD source within the cable. The tests highlighted the difficulty of triggering DC PD detection systems in conditions of relatively high background noise and the application of different triggering systems is now being investigated. Outline procedures for the application of PD detection to tests on full-size HVDC cable have been developed and work continues on the improved integration of UHF radio, radio, RFCT and IEC 60270-compliant techniques.
Collaborative partners	
R&D provider	**University of Southampton**

<table>
<tr><th>Project title</th><th colspan="3">Seismic Analysis of Electricity Towers and Substation Structures</th></tr>
<tr><td>Project Engineer</td><td colspan="3">David Fidler / David Woodcock / Gavin Chatley</td></tr>
<tr><td>Description of project</td><td colspan="3">To provide assurance that the current design specification is adequate to cope with the largest credible earthquake in the UK.

The objective of this project is to provide assessment information relating to structures selected from two example substations and for two transmission towers. The two substation configurations to be considered are a gas insulated substation (GIS) and an air insulated substation (AIS) ensuring the largest section of civil structures can be covered. The locations were chosen in order to take account of particular structures and that reside in the highest peak ground accelerations across the UK as stated in a British Geographic Study.

Two types of transmission tower types have been selected to be analysed, these are the structure type - L2 and L6. These represent a high population of the overall number of towers on the system.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £5k
External £55k
Total £55k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£55k</td><td>Projected 2013/14 costs</td><td>£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="3">Given the recent large seismic activities around the world and the increase in focus on the energy industry since the Fukushima nuclear crisis, the UK has issued its own report:

“Japanese earthquake and tsunami: Implications for the UK nuclear industry” HM Chief Inspector of Nuclear Installations September 2011.

This report attempted to apply relevance to the UK from the Fukushima nuclear crisis and clearly details the tsunami and earthquake experiences in Japan.

“ The direct causes of the nuclear accident at Fukushima, a magnitude 9 earthquake and the associated 14m high tsunami, are far beyond the most extreme natural events that the UK would be expected to experience..”

On review of National Grid Electricity Transmissions current policy there is no mention of a design standard for seismic activity in the UK. Substation equipment and some civil structures are however, designed to withstand short circuit current faults which is expected to exert a greater force on the civil structures than the largest earthquake expected to be seen in the UK.</td></tr>
</table>

Type(s) of innovation involved		Project Benefits Rating	Project Residual Risk	Overall Project Score
Expected benefits of project	This project will be used to inform the business better on the potential requirement to readdress the civil policy that is currently in place. Due to the imminent application of the Eurocodes to the construction of Substations, it is essential National Grid understand the risk associated to earthquakes. Eurocode 8 and the UK National Annex BS EN 1998-1 detail the requirements for the design of structures for earthquake resistance. By understanding the potential risk to electricity towers and substation structures, an informed policy document around the design of seismic activity will potentially remove the requirement for future seismic assessment on new construction. Seismic assessment of a new construction may include projects similar to this project proposal, a detailed seismic assessment and a report on the Eigen analysis of determined structures within the new construction, taking account of particular structure forms and / or equipment supported which is assessed to be the most sensitive or critical to operations. This is a strategic piece of work to assess the risk of the impact that an earthquake could have on National Grid, assessing two main areas of concern being Substations and Overhead lines. Cables and interconnectors are not covered in this study.			
Expected timescale of project		Duration of benefit once achieved		
Probability of success		Project NPV = (PV benefits – PV costs) x probability of success		
Potential for achieving expected benefits	High – Mott MacDonald's have a good working relationship with National Grid and the relevant technical expertise to conduct the study. Mott Macdonald have modelled the impact of short circuit faults on National Grid structures so as well as having experience with working with National Grid they also have the relevant expertise to model the civil structures and the stresses they would undergo given a large UK seismic activity.			
Project progress [Year to End of March 2013]	Drawings were collected for the L2 and L6 towers, GIS and AIS substations and shared with Mott MacDonald. This initial study has been completed with a report handed over to National Grid in September 2012. The report contained structural analysis completed with visualisation, highlighting structural members that would be placed under excessive force. This work was completed for a worse case scenario and has identified further work that will need to be conducted analysing the structural integrity of the assets when subjected to a realistic scenario. A second part of this follow up work will be investigating the standards needed to be completed to ensure our policy aligns with the Eurocodes 8 as the initial study has proved the need for further work.			
Collaborative partners				
R&D provider	Mott Macdonald			

<table>
<tr><td>Project Title</td><td colspan="4">Cables with Long Electrical Sections</td></tr>
<tr><td>Project Engineer</td><td colspan="4">Sam Mumba</td></tr>
<tr><td>Description of project</td><td colspan="4">This project will provide National Grid with;
An understanding of the steady state and transient performance of cables with long electrical sections.
An awareness of the failure mechanisms and life limiting factors of cable sheath voltage limiters (SVLs).
Recommendations for the future of operation and maintenance of cables with long electrical sections.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £5k
External £48k
Total £53k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£342k</td><td>Projected 2013/14 costs for National Grid</td><td colspan="2">£108K</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">In 2000 – 2002 midlife refurbishments were carried out on several cable circuits, mainly within London. As part of these refurbishment works the old link boxes were to be removed and new above ground pillars were fitted. At this time system studies were carried out and it was found that the length of major electrical sections could be extended, therefore reducing the number of link pillars that were required, eliminating the need for extra easements to be obtained and reducing ongoing maintenance requirements. However it has been found that circuits where the length of the electrical sections has been extended are suffering from multiple failures of the SVLs fitted to the cable bonding system. These SVLs are generally installed in public places and are critical to the circuit operation. As a result of this multiple circuits have been placed on enhanced maintenance regimes. These regimes require a major maintenance to be carried on the affected circuits annually opposed to being carried out every 3 years. Long electrical sections are also of interest as several new cable circuits are proposing to be installed with long electrical sections.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>9</td><td>-2</td><td>11</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Understand the impact on induced transient voltages on long electrical sections. National Grid currently has six circuits that are affected by these phenomena and further circuits are planned for the future.
Provide understanding of SVL failure mechanisms to feed into Risk and Criticality based maintenance frequencies.
Allow maintenance frequency to be reduced from Annual Enhanced to standard 3 years.
Enhanced maintenance regime costs in the region of £60k annually and requires 2 members of staff per</td></tr>
</table>

	outage, 6 circuits for 1-2 weeks. If a solution can be found to return these circuits to a standard maintenance regime (£10K every three years) would save finically each year in addition to increasing staff availability. • This fault has caused a major safety concern as documented in the incident investigation (SER19/11 and IMS Ref Number 261106). • The circuits that are subject to the induced transient voltages are generally situated in London and outages significantly decrease network availability.		
Expected timescale of project	**3 years**	**Duration of benefit once achieved**	**8 years**
Probability of success	**80%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£439287**
Potential for achieving expected benefits	**This proposal seeks to build on a successful record of work relating to cables and accessories at the University of Southampton.** • **The Tony Davies High Voltage Laboratory has over 40 years of experience of using both numerical modelling and experimental work relating to cable systems** • **Staff at the University of Southampton have undertaken fault investigations and forensic analysis of cable systems in Europe, America, the Middle East, Asia and Australia** • **Staff at the Uinversity of Southampton have recently been involved in installing monitoring equipment on transmission cable assets.** **Based on this extensive expertise and experience it is highly likely that the project will have successful outcomes and be deployed within National Grid.**		
Project progress **[Year to End of March 2013]**	**A review of National Grid fault reports is being undertaken to identify the damage suffered by SVLs and associated bonding leads during previous major faults (e.g. stop joint failures). Samples of damaged and undamaged SVLs have been secured for laboratory investigation. The damaged SVLs, primarily from the Hurst – New Cross 275 kV cable circuits will be subjected to forensic examination to assess the extent of any damage. Undamaged SVLs from Didcot Stores are being electrically tested to determine their operating characteristics. Both series and parallel operation of the SVLs will be examined.** **Some initial modelling has been carried out to study the likely voltages experienced by the SVLs during normal operation and transient stressing. For normal 50 Hz operation, even at the maximum winter rating, the maximum voltage across any of the SVLs is unlikely to exceed about 325 V. It seems most unlikely that this could be causing any damage; hence we need to consider the various transient events that the cable system must withstand. When considering the cable charging**		

	transients, increasing the section length does not increase the currents or voltages involved (in fact it tends to reduce them slightly), but it does however increase the duration of the voltage-limiting events; this duration increases approximately in proportion to the length of the sections. It may be that the SVLs are simply getting too hot during such events. **Some basic calculations with regard to the charging transients (concentrating on the energy likely to be dissipated in the SVLs) suggest that any residual charge on an isolated cable conductor may be detrimental to the SVL. Residual charge, resulting from the cable being switched out of service, is not normally considered a problem for the main insulation of an oil-filled cable, but could be affecting the performance of the earthing system. Indeed, factors which adversely affect the performance of the main insulation (e.g. high temperature or high moisture content) will increase the rate at which residual charge dissipates and may improve the reliability of the earthing system. However, further data from site will be needed to improve the modelling before any firm conclusions can be drawn.** **An outline proposal for an on-line SVL monitoring system has been developed. This would allow the full, in-service operating characteristics of the SVLs to be recorded. In reviewing the design, concerns were raised about electrical clearances within the earth bonding system and a simplified monitoring system is being developed.**
Collaborative partners	
R&D provider	**Southampton University**

Project Title	GPS Installation Condition Assessments & interference Monitoring System Installations		
Project Engineer	Phill Grant		
Description of project	A condition assessment and report on the condition of global positioning system (GPS) installations at 3 National Grid substations which will help determine how vulnerable a typical GPS installation is to GPS signal blocking/imitation/interference which can all have detrimental effects on National Grid protection systems. Note: interference can be introduced by adjacent National Grid equipment, this was found during field tests at Ninfield substation. The aforementioned threats can have short term consequences to National Grid (Olympics) and long term consequences (transmission system stability) by potentially in the worst case causing mal-operations on the system. The main objective which will be determined by the assessment of the installation of "24/7" GPS signal blocking/imitation/interference detector at 3 National Grid substations which will assess whether National Grid should be concerned about its extensive amount of equipment utilising GPS which is already installed on the system. The selection of the 3 National Grid substations will be based on criticality, i.e. next to busy motorways and/or where there are known problems which may be commonly occurring or infrequent but prolonged.		
Expenditure for financial year	Internal £6k External £23k Total £29k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£29k	Projected 2013/14 costs for National Grid	£0K
Technological area and/or issue addressed by project	Issue – A previous R&D project in 2009 had laboratory and on-site testing carried out on National Grid protection GPS timing receivers by CPNI, this testing found that: ▪ The GPS timing receivers are highly vulnerable to denial of service jamming which can be caused by commercially available GPS jammers (~£100) at line of sight ranges of up to 8km. ▪ Examples of jammers being used are documented meaning threat is real and genuine. ▪ Imitation of the genuine GPS signal is possible and time drift can be inflicted upon GPS timing receivers which would have a significant impact on National Grid protection systems via potential mal-operations. Proposals to solve the issue are: ▪ Installation of more robust GPS timing receivers ▪ Review and adjustment of current GPS installation techniques ▪ Removal of GPS reliance and switch to fixed communication circuits.		

Type(s) of innovation involved	Significant	Project Benefits Rating 7	Project Residual Risk -7	Overall Project Score 14
Expected benefits of project	The benefit accrues from assurance of whether GPS-synchronised unit protection systems are totally reliable or not and whether they have a heightened chance of mal-operating than non GPS-synchronised unit protection systems. ▪ Short term benefit: added confidence in system stability during Olympics and the possibility of introducing risk mitigations based on results of this R&D project. ▪ Long term benefit: added confidence in system stability for the remainder of GPS-reliant protection systems lives. Also, this project will give National Grid a better indication of whether National Grid should switch BT MegaStream communications paths to more robust services provided by Cable and Wireless. Further potential benefits include: ▪ The detection and prevention of any intentional/unintentional attacks on National Grid sites that have this monitoring equipment fitted to them which would avoid generation change costs etc whilst maintaining system stability ▪ Decrease in the amount of 'Loss of GPS' alarms that require looking into (resource) if this R&D project identifies improvements to GPS installations. ▪ Decrease in field staff call outs. ▪ Review or change in maintenance policy if this is incorrect. ▪ Ability to define installation practice rather than leaving to suppliers. ▪ Determine if GPS is the best solution. ▪ Determine the need to look at alternative technologies for time synchronisation. ▪ Reduction in call outs for alarm investigation. ▪ Improve reliability statistics. ▪ Influence implementation strategy and policy and investment strategy if a change in direction or improvement is required.			
Expected timescale of project	1 year	Duration of benefit once achieved	8 years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£0	

Potential for achieving expected benefits	**The assessment is very likely to be successful in determining the robustness of National Grid GPS-based equipment to GPS signal blocking/imitation/interference. It will also give an indication into whether National Grid's GPS installations are installed in a way which means they are most likely to receive prolonged sufficient GPS reception which is very important to the functioning of GPS-synchronised unit protection.**
Project progress **[Year to End of March 2013]**	**All 3 sensors are now installed at St Johns Wood, Cardiff East & Lackenby Substations. After numerous teething issues, the sensors are now communicating to the Chronos servers over the National Grid RAMM network. It is currently early days but we are trying to match any losses of GPS on GPS-based protections with events picked up by the Chronos sensors at the associated site.** **The initial thinking was that the sensors would only be installed and monitored for 3 months but it has been agreed that the period of monitoring is left relatively open ended, as it will give more chance of making findings which would be just as beneficial for Chronos as it would be for National Grid.**
Collaborative partners	
R&D provider	**Chronos Technology Limited**

Project Title	Reliability assessment of system integrity Protection schemes (SIPS)		
Project Engineer	John Fitch		
Description of project	The key objective of this project is a reliability assessment of existing System Integrity Protection Schemes (SIPS) (called Operational Tripping Schemes (OTS) in National Grid). The project will evaluate current architectures and technical solutions already deployed and the business and network impacts faced by the probabilistic risks in setting, arming and, failure to operate and mis-operation of these schemes. This will support the development of policies and specifications to help direct future requirements for SIPS architectures, which may need to meet higher levels of security and dependability, in a more uncertain and flexible transmission network.		
Expenditure for financial year	Internal £5k External £54k Total £59k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£112k	Projected 2013/14 costs for National Grid	£53K
Technological area and/or issue addressed by project	The reliability of System Integrity Protection Schemes (SIPS) (called Operational Tripping Schemes (OTS) in National Grid) to manage circuit thermal and network stability issues, will become increasingly important, with the expansion and increased utilisation of the transmission network. Over the next 10 to 20 years, it is expected that the transmission system will grow and change significantly, as larger off shore renewable generation is connected, new and larger nuclear stations built to replace the existing fleet and many of the existing coal fired power stations close down. In addition, with more HVDC connections from off shore wind farms, connections to Europe and Scotland and with more use of dynamic reactive plant (such as series compensation), new system stability and circuit loading constraints could emerge. At the same time, significant substation and circuit asset renewal and upgrade programmes will take place which will require SIPS to be used more frequently and the consequences of failure to be more significant. The probability of failure and adverse operations encompasses the impacts of both dependability- and security-based mis-operation and also delayed operation cases. As the number and complexity of SIPS in operation increases in National Grid (to overcome these challenges of a future constrained and stressed network infrastructure), it must be ensured that their performance and cost is optimised against the risks, to ensure the necessary the reliability requirements of National Grid's network continue to be met and to prevent and manage undesirable situations occurring. Some work has been done already on the evaluation of SIPS reliability from data gathered from North America and these techniques have been applied as an example to National Grid's		

	Dinorwig Intertrip scheme to demonstrate applicability. This identified the main causes of SIPS mis-operations and proposed a method for assessing SIPS reliability and how this could be applied to the Dinorwig Intertrip Scheme. In addition there are potential risks introduced to the transmission system by unintended interactions between neighbouring and overlapping SIPS and these will also be investigated.. SIPS have typically been designed for dependability rather than security; however security will become increasingly important with the potential technical and economic impact of mal-operations on a more dynamic, complex and constrained system.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		8	-8	16
Expected benefits of project	This work addresses understanding the consequences of low probability, high impact events and how systems can be specified and maintained to reliably manage these events throughout their life. The potential benefits are: Ensuring reliability and availability of the National Grid network is maintained, while it expands and changes to meet the needs of the "gone green" scenario. Understanding of the optimised risk, cost and performance balance for future SIPS investments which typically cost > £1m. Ensuring SIPS technical designs are able to deliver reliably, the business and technical requirements for the future.			
Expected timescale of project	2 Years	Duration of benefit once achieved	8 Years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£38714	
Potential for achieving expected benefits	The probability of success is considered to be high. This work has been applied previously to reliability data received from North America as part of an EPSRC supported PhD at the University of Manchester. It builds on this research as a one year post doctoral research assistant, but is now to be tailored for National Grid and directed to meet the SIPS challenges faced by National Grid in the future.			

Project progress **[Year to End of March 2013]**	***The researcher has developed his initial study work and applied it to a specific example National Grid system (Dinorwig OTS) to help develop the necessary concepts and validate the tools further. The annual National Grid equipment and fault data for OTS and Special Protection Schemes have been analysed and an interim report produced on the architecture and practices in National Grid.*** ***Comparisons have been made with published data from other utilities and a new methodology has been developed. This methodology and the results to date are to be described in a journal paper (currently being submitted). This methodology is to help evaluate different architectures and designs for future equipment reliability and availability and their impacts on system security and dependability.*** ***Information on communications services reliability is being added into the process, as this can form a major part of the overall system reliability statistics.*** ***The next stage is to bring in cost models of systems using actual examples of OTS schemes installed by National Grid. This will help define the future cost /risk options of different architectures and solutions.*** ***The work is being linked with other research at the University of Manchester on PMUs/SmartZone, which can be used for conditioning OTSs or as part of separate Wide Area Protection and Control solution. This will ensure that reliability is considered in the design and application of these new schemes.*** ***It is planned to run a feedback session with Market Operations to illustrate the work to date and seek their views on availability and reliability of National Grid's current schemes from an operator perspective.***
Collaborative partners	
R&D provider	**University of Manchester**

Project Title	Novel Backfill			
Project Engineer	Richard Attwell			
Description of project	This project aims to deliver a novel material for backfilling cable trenches that requires much less time and a non-specialist workforce to excavate. This proposal seeks funding for a trial and demonstration of a new (to the GB system) backfill from the US & Canada, and the thermal testing that goes with it. This will be tested as soon as possible on a critical part of the network.			
Expenditure for financial year	Internal £4k External £9k Total £13k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k	
Total project costs (collaborative + external + [company])	£13k	Projected 2013/14 costs for National Grid	£0K	
Technological area and/or issue addressed by project	Currently, cable backfill is concrete bound sand. This sets essentially like concrete, and cannot be dug out easily without specialist teams due to risk of damage to the cable below. Currently, it could take up to three weeks to excavate the cable properly with specialist contractors having to use sandblasting to excavate the cable. This is both labour intensive and expensive. The proposed method gives a backfill that can be removed with a shovel, and as such, non-specialised contractors can be used to carry out the work, and the time delay in reaching the cable is significantly reduced (to approximately 3 days).			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score
		21	-8	29
Expected benefits of project	There is a current fault on a critical circuit that has prompted this work. The costs being incurred from this circuit being out are around £150k per day. This gives an excavation cost of £2.25m in constraint costs alone.			
Expected timescale of project	1 year	Duration of benefit once achieved	8 years	
Probability of success	90%	Project NPV = (PV benefits – PV costs) x probability of success	£164149	
Potential for achieving expected benefits	High. This technology has been used on other international cable systems, but this is the first time on the GB system..			

Project progress [Year to End of March 2013]	**Up to March 2013 the R&D project has only just started. The University of Southampton had taken delivery of quarry sand near a site for sample testing. Tests were completed on a large range of sand/cement ratios. This also included different moisture content levels. The output of this work was to create a graph of thermal resistivity against sand/cement ratio for the site. It was found that with further research the specified 20:1 by weight ratio currently used could be weakened to a 30:1 ratio, which would mean excavation time would be reduced due to the use of a weaker mix. This however still needs further exploration.**
Collaborative partners	
R&D provider	**University of Southampton**

<table>
<tr><th>Project Title</th><th colspan="3">Digital Risk & Security</th></tr>
<tr><td>Project Engineer</td><td colspan="3">Robert Coles</td></tr>
<tr><td>Description of project</td><td colspan="3">. Seconomics FP7

• To complete technical research to understanding the cyber threats affecting National Grid
• To undertake economic analysis and modelling of the possible incentives and behaviours of critical national infrastructure (CNI) operators under different regulatory regimes.
• To provide an assessment of current and other regulatory framework that could apply to CNI operators in terms of cyber security and obtain consensus of a preferred regulatory regime.

Intentional Electro-Magnetic Pulse Risk Assessment

• To gain a technical understanding of the current capability to generate an intentional electromagnetic pulse that could damage computer equipment and to understand the type and extent of damage that may be caused.
• To gain an understanding of the vulnerability of current infrastructure from electromagnetic effects on equipment, systems and infrastructure assets.
• To inform the specifications with respect to required infrastructure to withstand such attacks.

Cyber-security Research

• To develop a cyber-security research agenda for National Grid.
• To consider what general security research is applicable to National Grid and what National Grid and energy sector-specific requirements must be addressed.
• To identify and develop programmes to address these issues.
• To identify and develop a group of collaborations and funding mechanisms/sources.
• To work with UK/US agencies and the energy sector to develop shared activities and communities with common interests in CNI cyber-security.
• To initiate National Grid’s position as a thought-leader in energy cyber-security research and place National grid as the natural convener of dialogue in energy sector cyber-security.</td></tr>
<tr><td>Expenditure for financial year</td><td>Redacted</td><td>Expenditure in previous (IFI) financial years</td><td>Redacted</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>Redacted</td><td>Projected 2013/14 costs for National Grid</td><td>Redacted</td></tr>
</table>

Technological area and/or issue addressed by project	To complete technical research into cyber threats, testing of equipment and infrastructure for UK computer managed assets. Ultimately, to try to provide solutions for managing cyber threats to National Grid assets and systems.				
Type(s) of innovation involved	Redacted	Project Benefits Rating	Project Residual Risk	Overall Project Score	
		Redacted	Redacted	Redacted	
Expected benefits of project	**Seconomics FP7** In the UK National Grid is not subject to mandatory regulation for cyber security. European regulators have mentioned in various forums that regulating CNI operators in terms of cyber security is an option. The purpose of this work is to provide recommendations to the European Regulators of regulatory systems that would incentivise the operator's to be secure. Through providing these recommendations the regulatory process can be driven to ensure that onerous regulatory frameworks are not imposed. This allows National Grid to have early engagement and shape the regulatory framework at a European level. Without this engagement the European regulator could impose regulatory framework around cyber security that does not incentivise the CNI operators to secure themselves or worse, could be detrimental to the security of the CNI. This could also be very burdensome to the operators themselves and increase the cost of demonstrating compliance to any new regulations in cyber security. **Intentional Electro-Magnetic Pulse Initial Risk Assessment** The work once complete will identify vulnerabilities and recommend pragmatic mitigation. This allows National Grid to understand and manage risk effectively to allow the business to operate safely and securely as well as cost effectively.				
Expected timescale of project	Redacted	Duration of benefit once achieved	Redacted		
Probability of success	Redacted	Project NPV = (PV benefits – PV costs) x probability of success	Redacted		
Potential for achieving expected benefits	Very high based on previous research undertaken and the research collaboration.				

Project progress
 	
[Year to End of March 2013]
	Intentional Electro-Magnetic Pulse Risk Assessment
	
	The scope of the work so far can be organized under three headings:
	
	Understanding Effects
	• **Supporting customers in the development of operational concepts.**
	• **Providing thought leadership on research priorities.**
	
	Enabling Operations
	• **Supporting customers on integration and interoperability issues**
	• **Research support aimed at addressing the non-equipment defence lines of development (DLODs).**
	• **Test and Evaluation.**
	
	Assessing Vulnerability
	• **Supporting UK Govt. and Infrastructure Owners/Operators.**
	• **Technical Visual Assessment.**
	• **Instrumented Technical Survey.**
	• **Evidence-based hardening consultation.**
	
	The work remaining to be done is the following:
	• **Task 1: One additional site pre-survey/Technical Visual.**
	• **Assessment (TVA) – Gas Compressor Chelmsford.**
	• **Task 2: Update CPNI Guidance on IEMI to include:**
	  – **General observations from the TVA's conducted so far;**
	  – **Data on the intrinsic protection afforded by perimeter fence types and buildings (Task 3, if selected);**
	  – **Data on equipment susceptibility (Task 4, if selected);**
	  – **Updated information on 'threat' environments.**
	• **Task 3: Intrinsic radio frequency protection of perimeter fences and buildings.**
	• **Task 4: Susceptibility testing of assets.**
	• **Task 5: Gap Analysis of National Grid electromagnetic compatibility specifications.**
	
	Seconomics FP7
	
	Digital Risk & Security has appointed Dr. Raminder Ruprai to work 50% on this project, in close co-operation with the

University of Aberdeen.

An overview of the implementation mechanisms of policy approaches regarding the question of rules-versus-principles based in enacting policy requirements has been developed. Whilst this is a well-known issue in most public-policy contexts, it has not been studied widely in the area of rule setting in security. This concept will be considered using some specific examples from critical national infrastructure.

Moving on from policy implementation, the needs for security policy in an economic context will be developed by outlining a series of models of security scenarios. In each case, the need for placing constraints on actions (due to incentive incompatibility) of individual agents to maximize the global level of welfare will be illustrated.

A detailed systems modeling framework with explicit representations of relevant systems architecture, and logical methods for reasoning about such models will be considered. A simulation modeling tool (Gnosis) has been outlined that captures the mathematical structures required for systems modelling. The Gnosis modelling tool currently does not include specific representations of economic theory. Part of the work is to illustrate how to use mathematical modeling languages such as MatLab to integrate the necessary mathematical structures and integrate them with notions of utility theory and welfare to encapsulate better the economic interactions inherent in such models.

Specific guidance on integrating economic and systems models in a security problem context have been provided. A worked example of airport security architecture has been outlined. The systems model in this version of the model has a policy function based on observed metrics that can be used to compare performance of different configurations of the airport security architecture. The core features of the policy function have been derived.

A series of results broadly related to market-based pricing or real options models have been developed. These models are useful when there are exogenous risks, and allow for the calibration of monetized cost benefit analyses. The models typically measure risk next to a known set of benchmarks with easy to value properties (e.g., using an asset pricing model, such as a Geometric Brownian motion value process or a multi factor asset pricing model such as the famous Capital Asset Pricing Model (CAPM)). The objective of these models is to impute discount rates on assets that allow for a) comparison and b) addition of risks. These risks can be converted via a market mechanism to additive costs. This approach is useful when there is at least one easily comparable liquid asset.

A series of micro theory models of externalities and incentives (good when the architecture is simple, intractable to formulate otherwise) useful for under- standing how to build contracts and incentive structures that improve welfare have also developed. This includes principal agent problems, models of

externalities and models of public policy, institutional analysis and design. An overview of insurance in this context, again with a view to monetization/or cardinality of preference of the impact of security policies has been presented.

A model that explicitly analyzes the balance between rules- and risk-based regulation is currently being developed. This model will be explored computationally in the context of the NERC CIP regulatory regime.

Cyber-security Research

- **Appointment of Prof. David J. Pym of Aberdeen University as Director of Cyber-security Research for a period of 3.5 yearrs from 1 March 2013.**
- **Projects are being scoped in the following areas:**

  Supply chains/Service level agreements

  Organizational culture

  Bring your own device (BYOD)/mobile devices

  CPNI alignment

The FP7 Seconomics project: This project is addressing concerns about the design of regulatory regimes and the right balance between rules-based compliance and risk-assessment-based security management.

Also linked are:

- **GCHQ/ESPRC ‘Productive Security’, with UCL and University of Aberdeen (culture & modelling)**
- **New EPSRC project (security modelling/economics) Universities of Aberdeen and Bath, National Grid, HP Labs. This is basic research in security modelling/economics, but is strongly grounded in the intended applications.**
- **Seeking further engagement UK funding:**

With CPNI/EPSRC/GCHQ. Pym has been advising CPNI on a new security research institute in industrial control systems.

Possible Technology Strategy Board engagement with a similar programme.

There is an opportunity for National Grid to align some innovation funds with CPNI’s institute.

Research Councils: Outline bid submitted to the BACCHUS

	programme: Minding the Policy-Implementation Gap Academic security economics publications in sustainability/resilience and in the need for public policy interventions in information security are in progress.
Collaborative partners	National Grid Electricity Transmission, National Grid Gas Transmission Seconomics FP7 University of Aberdeen (primary) and others as above.
R&D provider	As above

Project Title	Dinorwig Thermal Cycling and Cable Rating			
Project Engineer	Sam Mumba			
Description of project	The project aims to undertake a detailed study on the thermal cycling effects on the Dinorwig cable circuits with particular emphasis to the stop joints. The live data captured on site will enable a model to be developed of the stop joint using Finite Element Analysis. The results of this analysis should yield better understanding on the expected performance of these stop joints under differing load patterns as well as shed light on any relevant amendments regarding assumptions made in the current cable ratings model.			
Expenditure for financial year	Internal £7k External £35k Total £42k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k	
Total project costs (collaborative + external + [company])	£303k	Projected 2013/14 costs for National Grid	£262K	
Technological area and/or issue addressed by project	Over recent years the 400kV electricity connection for Dinorwig Power Station has suffered from poor reliability problems associated with abnormally high Dissolved Gas levels in the cable fluid. These levels have forced National Grid Electricity Transmission to switch out the Dinorwig-Pentir 1 circuit in 2012 resulting in a circuit outage to replace the 'gassing' stop joint accruing costs of circa £150k per day. An identical issue occurred in 2011 on the Dinorwig-Pentir 2 circuit with identification of another 'gassing' stop joint. These incidents have prompted an action to probe further into the likely root cause as well as further studies to understand the resultant effects (pertaining to stop joints) from an aspect of thermal cycling.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score
		9	-3	12
Expected benefits of project	It is expected that the results of this study will feed into the strategy of actions and recommendations aimed at reducing the risk of a further reoccurrence and reducing any associated outage needed to replace a 'gassing' stop joint, thereby avoiding customer impact and costs.			
Expected timescale of project	1 Year	Duration of benefit once achieved	8 Years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£244110	

Potential for achieving expected benefits	**This proposal seeks to build on a successful record of work relating to cables and accessories at the University of Southampton.** • **The Tony Davies High Voltage Laboratory has over 40 years of experience of using both numerical modelling and experimental work relating to cable systems.** • **Staff at the University of Southampton have undertaken fault investigations and forensic analysis of cable systems in Europe, America, the Middle East, Asia and Australia,** • **Staff at the University of Southampton have recently been involved in installing monitoring equipment on transmission cable assets.** **Based on this extensive expertise and experience it is highly likely that the project will have successful outcomes and be deployed within National Grid.**
Project progress **[Year to End of March 2013]**	**The first phase of the project entailed installing thermocouples and associated termination boxes. This phase of the project is nearly complete but an outage is necessary for final jointing and completion of all connections. An outage is due in the first week of September but further installation work for the comms links and data capture are scheduled to commence prior to the outage.** **This will then lead into Phase 2 where the data capture and analysis will commence. Phase 3 will entail modelling using Finite Element Analysis, comparing modelled and live data upon which conclusions will be drawn as highlighted in the objectives.**
Collaborative partners	
R&D provider	**University of Southampton**

Project title	OHL Data Collection (Original Title – Data Visualisation)			
Project Engineer	Matthew Grey			
Description of project	The feasibility study will assess whether a map platform (initially Google Earth) will provide a suitable tool for consolidating all Overhead line (OHL) condition and asset information data in a way, which allows for easy access in a geographical format. It will also look at the potential to layer real time information feeds that are available (e.g. met office, environment agency information) over the geographical map lay out. The study will initially focus on one OHL route, however this will have the scope to be extended nationally and for use by Substations, land and development etc., providing a platform for other information including live feeds. The study has produced a positive outcome and we are now moving on to the next stage of development.			
Expenditure for financial year 11/12	Internal £19k External £92k Total £111k	Expenditure in previous (IFI) financial years	Internal £8k External £63k Total £71k	
Total project costs (collaborative + external + [company])	£182k	Projected 2012/13 costs for National Grid	£0k	
Technological area and/or issue addressed by project	A number of information sources relating to overhead line (OHL) assets; their condition, ranging from actual asset information, condition assessments, foot patrols, helivisuals, Schwem, Cormon and conductor sampling. This is all held in different file locations and different databases, making it difficult to access all ranges of information efficiently regarding a particular asset or route.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		12	-2	14
Expected benefits of project	With the advent of the strategic asset management (SAM) platform and a need for the business to have access to accurate real time data, the concept that has been proved will be expanded and a working model produced using a suitable mobile device, mapping system and secure communication link connecting the mobile device to the data base platform. In addition to the above, a further benefit would arise concerning the annual foot patrols undertaken by OHL operatives. OHL operatives inspect and report on the visible condition of approximately 15,000 OHL towers per annum. Presently the information is gathered via a script loaded on a personal digital assistant (PDA) device and consists of 200+ questions which are repeated on each tower. There is a considerable delay period between collection of the data and limited visibility to the business. With a Mobile device linked to a live database the field operative would arrive at a tower, verify the tower location by global positioning system (GPS), followed by a download from the database of the last known asset data for that tower. The operative would then report by exception to the known			

	data, after which he would return the up to date information which, after verification, would lead to a database update in real time. Other benefits that this new system will bring are :- Display information for any given tower and both associated spans (i.e. both high & low side) – where as at present it only shows 1 tower and 1 span. Ability to display, for any given span, asset condition on both circuits at the same time – currently the existing system only displays 1 circuit at a time. Resulting in the linesmen having to complete all questions for 1 circuit before completing questions for the other circuit, even though the linesman is walking alongside both circuits at the same time. Have the function to take a picture of any asset condition and send this to an OHL delivery engineer i.e. significant conductor damage, anti climbing device damage, insulator failures etc.		
Expected timescale of project	**4 years**	**Duration of benefit once achieved**	**5 years**
Probability of success	**80%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£255k**
Potential for achieving expected benefits	**On target to complete the proof of concept and device selection during the summer of 2012.** **The next stage during will be to use the device and the software database on an actual foot patrol.**		
Project progress [Year to End of March 2013]	**During 2012/13, the project has moved forward to the point of full trials to collect footpatrol data. A number of devices were procured and distributed to four OHL teams and footpatrol data was collected for approximately six routes. This data has successfully been transferred into C3 Global's SAM database and reporting tools have been developed that allow for interrogation of data and visualisation of results. Following the field rollout, feedback has been sought and a number of issues, mainly around software user interface, have been identified that are currently being addressed. It is anticipated that all outstanding issues will be resolved prior to the next footpatrol season and that the project will be recommended for full rollout at that time to allow for a complete set of OHL footpatrol data to be collected in the winter of 2013/14.** **During 2011/12 the project redesigned and developed a new OHL asset condition database and established a series of new foot patrol scripts that will be placed onto the new handheld device. A database was in production to hold all asset condition data on individual towers and spans. The concept of overlaying this data onto a mapping platform has been proved with the possibility of aligning this database to the SAM platform, to allow real time interaction between this asset database and the operative in the field.** **Suitable devices have also been established to use on the final proof of concept field tria and how we collect and capture data. The possibilities of moving to a tablet device with GPS capability have been investigated. This would allow the use of real time mapping to match assets to data.**		

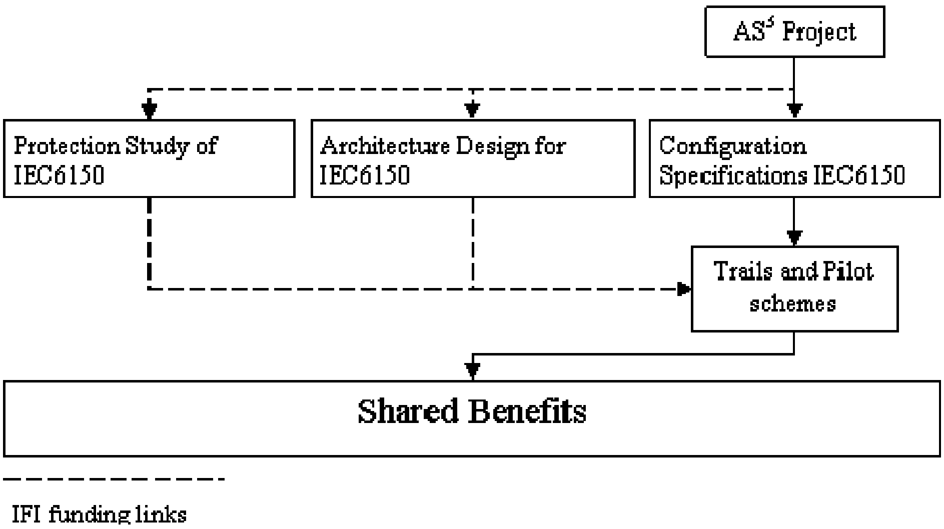
Collaborative partners	
R&D provider	**C3 Global**

Project title	Architecture for Substation Secondary System (AS3) Project			
Project Engineer	John Fitch			
Description of project	The project entails: ▯ Review of current policy and practice To identity and understand the whole life cycle issues for the existing protection and control systems. ▯ Strategy document for substation secondary systems To develop a road map to show the strategy for the application of protection and control new technology in the short, medium and long term. ▯ Feasibility Study To investigate new technologies. To collaborate with major suppliers/Alliances to share information. To standardise Substation primary and secondary system interface. To benchmark with leading utilities. ▯ Trials and Pilot schemes To try the new approach in parallel with existing systems with outputs disabled -“Piggy-back” trials. To apply the new approach to some real projects as pilot schemes (Min 2). ▯ New Policy To develop a new policy for the substation secondary system, To develop associated technical specifications.			
Expenditure for financial year	Internal £54k External £10k Total £63k	Expenditure in previous (IFI) financial years	Internal £213k External £536k Total £749k	
Total project costs (collaborative + external + [company])	£749k	Projected 2013/14 costs for National Grid	£0k	
Technological area and/or issue addressed by project	To form a new policy for substation light current systems aimed at maintaining high availability and reliability of the transmission network by balancing the whole life-cycle risk, performance and cost of assets. To develop a new architecture for substation secondary systems by introducing new technologies, targeting a quicker and easier approach for the installation and replacement of protection and control equipment beyond 2011.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score
		10	3	7

Expected benefits of project

This project is to identify and understand the potential benefits and risks associated with designing and implementing new substation secondary system architecture. It will do this by deploying new technology/developments such as standard interface modules, bay process bus and IEC61850 communication protocol. It is important that National Grid take a leading role in this area to provide manufacturers with specification as to what is needed rather than being led into this system by the manufacturers.

AS^3 has linked IFI projects that contribute to the overall shared benefits of the project increasing the likelihood of success as the project progresses as shown below.



The benefits expected from this project will not be appreciated until the AS^3 system has been implemented. The full benefit of the project will only be seen when all AS^3 systems have gone through a complete life cycle estimated to be roughly 20 years.

This project will investigate the possibility of this new architecture which will have a long lasting interface to the primary plant, which should not have to be altered or replaced should the secondary systems need to be replaced.

This project is investigating the feasibility of achieving whole life cycle benefits, so that the asset life of light current system in a substation can be optimised.

The project will investigate benefits in the following areas:

- The design and development potentially can be standardised at all levels (station, bay and interfaces) within a substation. This will allow proven solutions be used repeatedly for different projects/sites, thus the project risks and resources will be minimised saving time and money.
    - The installation and commissioning will be much safer and quicker than traditional approaches. The “plug and play” will be possible for the installation and replacement due to use of IEC61850 based fibre optical bus and standardised interfaces. Therefore the required outages of primary system will be significantly reduced ensuring availability is maintained. Safety, health and environment are improved by reducing the need for cross-site secondary circuit

<table>
<tr><td></td><td colspan="3">cabling migrating associated risks.
The operation and maintenance could greatly benefit from the new approach. Full deployment of digital technology and removal of copper wirings should make the operation of the secondary system more reliable as faults can be more easily recognised and replaced. This would also challenge the traditional concept/requirements for maintenance. The new technology will enhance functions such as condition monitoring and remote access, which should further improve the operation and maintenance by providing real time information to enable the operator to take the best-informed action. Also this process will be safer as the new secondary systems transmit data of current transformer (CT) and voltage transformer (VT) analogue signals via bay process bus. This poses no safety risks of opening CT circuits, and hence improving the safety when the protection replacement is carried out with primary circuit in service.
The replacement and de-commissioning can be achieved in a quick “plug and play” manner. Components used will no longer be limited to a specific manufacturer due to Inter-operability/Inter-changeability facilitated by the IEC61850 protocol. This will significantly reduce the requirements and costs for the Post Delivery Support Agreement (PDSA). By enabling any unit to be replaced by any other IEC61850 machine therefore not tying National Grid into uncompetitive PDSAs
The new technology using IEC 61850 communication protocol will enable vendor interoperability and easier modification and extension of the secondary schemes, particularly allowing reconfiguration and feature enhancement by software means, rather than the modification of hardwiring as would have been the case in the past.
The fully digitised fibre optical architecture will also form an additional “isolation layer” for the electromagnetic noises from primary system. This will significantly improve the reliability of secondary systems and consequently reduce the requirements for the costly Electro-Magnetic Compatibility (EMC) for the protection and control devices.

A similar pilot scheme by GE has reported potential savings of 25% in the installation of secondary systems using a plug in and play system of installation.

Estimating a saving of approximately £50k (5%) per substation with AS3 implemented, with an expected roll out rate of approximately 50% of substations refurbished or newly built to have AS3 each year making a total saving of approximately £500k per year.</td></tr>
<tr><td>Expected timescale of project</td><td>3 years</td><td>Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td>50 %</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£19k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="3">Technically, it has a good potential to achieve expected benefits as
International committees such as IEC and CIGRE have set up working groups to carry out studies on relevant technical subjects; some standards and application guides have been published. National Grid</td></tr>
</table>

	is participating in most of the working groups directly or indirectly. • All the major suppliers have been working in this area for more than 10 years, product prototypes are being produced and tried. Some trials and pilot schemes with leading suppliers are planned within this project. • Some leading utilities such RWE, Tennet have started some pilot schemes. Benchmark with those utilities is one of the key feasibility studies within this project. • This project is governed and managed with a hierarchical structure including a sponsor, project board, project manager and working groups, to ensure that all the planned activities will be properly delivered. However due to market readiness and resource seconded to support System Strategy (ENSG Vision 2020), it is expected that the AS^3 project will be delayed for a period of 12-18 months
Project progress [Year to End of March 2013]	The work of AS^3 work was consolidated into 4 work streams (WS) with the focus on key deliverables relating to these areas: • WS1: R&D project for AS^3 Architecture & Reliability analysis • WS2: R&D project for Protection Performance Study with AS^3 architecture, • WS3: IEC61850 Configuration Guideline/Merging Unit Guideline • WS4: Siemens Process bus trial at Radcliff substation with Switchbox (SB) development Following resource prioritisation and views on technology readiness a revised programme was developed indicating that the AS^3 project would be delayed for 12 – 18 months. The remaining focus would therefore be on completing the R&D projects WS2 and WS3 deliverables and establishing two further pilot installations from NR Electric and ABB. 1. Review of current policy and practice AS^3 Working Group 1 has successfully completed this key deliverable. Seminars and workshops were held with National Grid internal departments and external suppliers to identify the whole life-cycle issues regarding protection and control systems. Some high level policy and specifications were also reviewed. 2. Strategy for the development of substation secondary systems Strategy Document SD(T)012 has been produced by AS^3 Working Group 2. This document specifies the strategy (road map) for the application of new technology in the development of the substation secondary system in the short, medium and long term. 3. Feasibility Studies 3.1. The draft documents for Testing & commissioning philosophy and Scheme. Implementation Strategy have been produced by WG8 and WG3 respectively. And a high level specification for Switch Box was drafted by Safety & Operation working group (WG9). WS1: AS^3 Architecture & Reliability analysis, • Produced proposal for the optimal AS^3 architectures.

- **Developed methodology for reliability/cost analysis to identify optimal architectures.**
- **Establishing testing facilities for the IEC61850 9-2 process bus products.**

Project is complete: For the detailed progress of WS1, see separate IFI annual report for "TAOOL146 AMRDE1044 10-11 Evaluation of process bus…"

WS2: Protection performance study

All the planned activities within WS2 are under R&D project "the Protection Performance Study with AS^3 architecture". The project is co-founded by Alstom Grid which jointly delivering some process bus systems/equipment with University of Manchester and bath for the testing. For the detailed progress, see separate IFI annual report for TAO/20627, the Protection Performance Study with AS^3 architecture.

3.2. WS3 has finalised the draft document "IEC61850 Configuration Guideline" with participation and contribution from all National Grid alliances/suppliers.

- **Using the same set-up, the working group was also assigned with a new task to explore the requirement for the merging units to meet the needs for all the protection and control functions/devices on the process bus as well as their interoperability and interchangeability. A "Merging Unit guideline" has been successfully drafted by the Working Group, which has also been forwarded to IEC TC38 as a reference for developing international standards**

3.3 AS a UK regular member, National Grid participates the following CIGRE working groups which are directly beneficial to this project:

- **B3-10 Primary / Secondary system interface modelling (Standardisation I/O signals), which is in the final stage of preparing a technical brochure.**
- **B5-27 Implications and Benefits of Standardised Protection Schemes.**
- **B5-24 Protection Requirements on Transient Response of Voltage and Current Digital Acquisition Chain/**

3.4. Benchmark took place with Tennet (Dutch) and RWE (German) for their pilot projects using Locamation and Siemens systems respectively.

4. Trials and Pilot Schemes

Dedicated working groups were set up with Alstom/SE alliance, ABB/Central alliance, Mitsubishi/SW alliance, Siemens/North alliance, to pursue options for these collaborations and *"Piggy-back" trials*.

Linked to WS2, Alstom made proposals to upgrade their existing trial at National Grid Osbaldwick substation to further develop it into a feeder bay trial with the AS^3 Architecture. This was not taken forward as Alstom did not have available mature technology that could be delivered within the required timeframe.

Under WS4, Siemens installed and commissioned a Process bus trial with "conceptual units" of Switchbox (SB) at National Grid's Ratcliffe substation. This WS is aimed to;

- **Finalise Technical specification for the Switchbox.**
- **Examine the philosophy for installation, tests & commission.**

- Trial with Siemens process bus technology at Ratcliffe substation.

Now all the planned activities under WS4 have been completed. Siemens has produced a final report to summarise the experiences/results from the site trial.

The Switch Box Technical Specification TS 3.24.89 and Technical Guidance Note TGN (E) 241 have been issued. Following completion, the trial has now been recovered to the laboratory at University of Manchester for further interoperability evaluation.

A Trial Feeder Protection solution from NR Electric (China) solution has been successfully commissioned on the Drakelow-Ratcliffe circuit consisting of two indoor protection cubicles and two outdoor Merging Unit cubicles, one at each end of the circuit. The protection relays and merging units are connected only by process bus fibres, significantly reducing cross site wiring. The scheme was successfully commissioned as a “piggy back” system in Nov 2012. The four IEC61850 protection and control panels were manufactured and tested in China and then transported to the UK where they were installed and commissioned on site by a UK project company (GSS). The system was successfully installed and commissioned in a 2 week outage period on the 400 kV circuit interfacing with conventional instrument CTs and VTs and plant contacts. The feedback from the sites engineers on the architecture, installation and testing process and some installation practice issues have been fed back to NR Electric to consider. To evaluate the reliability and integrity of the solution, it is planned to carry out a Trip and DAR of the circuit in May 2013. Records are to be collected from the relays on a regular basis and sent to NR Electric for evaluation. The trial is to run until April 2014, when it will be removed from the system and relocated to the University of Manchester as part of the interoperability evaluation project.

ABB has installed an IEC61850 trial system at Bodelwyddan substation on the Pentir-Bodelwyddan-Deeside circuit. Issues with site engineer resource and design assurance of the Design Intent Document (DID) and agreed drawings, prevented it being commissioned during the planned circuit outage. These issues are being resolved and it is hoped to move forward with commissioning in the second quarter of 2013. Additional non-conventional instrument CTs and VTs have been installed at Bodelwyddan to feed the process bus protection relays there. Conventional relays interface to conventional CTs and VTs at the remote ends. The whole system is a piggy back trial, overlaid on the commissioned traditional protection scheme. conventional systems. The trial is planned to be monitored for 2 years, when it will be removed from the system.

5. New Policy Statement and Associated Engineering Documents

Some high level strategy analyses have been performed on the management of technologies, risk assessment, long term costs/benefits. A business case interim report has been produced to summarise the study result to date.

Based on the first two year’s project progress as well as the development of IEC61850 technology and NG internal business, a strategic direction paper of the AS3 project was produced and approved by the project board to

- summarise the achievement to date,
- identify some earlier applications/benefits,
- confirm the further developments:

	ACHIEVEMENTS TO DATE: • Policy & Practice Review • SD(T) 012 Strategy Document for Substation Secondary Systems • AS^3 Generic Architecture – 4 key elements identified • IEC61850 National Grid configuration Guideline (final draft) • IEC61850 Merging Unit Guideline (draft) • Strategy for AS^3 Scheme Implementation (draft) • Philosophy for AS^3 installation, testing & commission (draft) • Switch Box TS 3.24.89 and TGN(E) 241(draft) • Cigre B3-10 ”interface model” Brochure (standard I/Os, primary) • AS^3 ”Business Case” Interim Report • Areva feeder unit protection trial at Osbaldwick Substation • Siemens' trial (process bus + Switch box) at Radcliffe Substation. STRATEGIC DIRECTIONS The key drivers and business needs for AS^3 project have not changed. The 4 key elements based AS^3 Architecture will provide a sustainable solution to the whole life cycle of light current assets, which can be implemented in stage approach: • IEC61850 station bus o Ready for single vender applications, o Need pilot schemes for vender interoperability using the National Grid IEC61850 configuration specification (draft). • Standard Bay Solutions(SBS) remain largely the same as SICAP • Switch box for the I/O interface should be deployed as soon as practically possible o Technical Specification finalised, low risks. o “Quick-win” benefits both SICAP and future AS^3 architecture. o covers all application scenarios-current, future & changeover. Further R&D: IEC61850 Process Bus o Merging unit (MU) Specification (draft) to be finalised. o Hybrid technology for feeder bay solution (one end process bus and other ends conventional), a potential replacement scenario. o I/O standardisation (P&C alarms and events).
Collaborative partners	A potential collaboration with National Grid US and PG&E from the west coast of US are under discussion/preparation.
R&D provider	ABB, Areva, Mitsubishi, Siemens, University of Manchester University of Bath

Project title	SALVO
Project Engineer	Michelle Le Blanc
Description of project	SALVO is a project to research and develop innovative approaches to decision-making in the management of mature assets. SALVO aims to develop simple, flexible and practical guidance and tools for determining what to spend and when in the following common, yet critical, decision scenarios: Individual activity or task level (for specific assets/groups of assets): "As the equipment ages, what changes to inspection, condition monitoring, functional testing or planned maintenance should I make?" "When is the optimal time to replace (or decommission) this equipment, and what are the cost/risk effects of delay?" "Should I replace with the same design (like-for-like), or with a technology change/upgrade/alternative design?" "Is it worth refurbishing the current equipment, to extend its life and, if so, by how much?" Is a (non-cyclic) modification project worthwhile, and how does this compete for value/priority with timing-sensitive or cyclic tasks (e.g. maintenance/renewal)? Programme integration level (only possible once the above questions can be answered individually and quantitatively): What is the optimal (life cycle value) combination of capital investment and operating/maintenance expenditures for a particular class of assets (i.e. optimising the mix inspection, maintenance and renewal)? What is the optimal integrated work programme (multiple activities for multiple assets) over the next XX years (including coordination opportunities, resource smoothing etc)? Given a specific capital investment budget, which projects or tasks should I spend it on? What are the investment and maintenance budget/resource needs for my asset portfolio in the next XX years? These questions all draw on certain common technical and process requirements. Such core components determine the SALVO R&D technical work elements (figure 1).

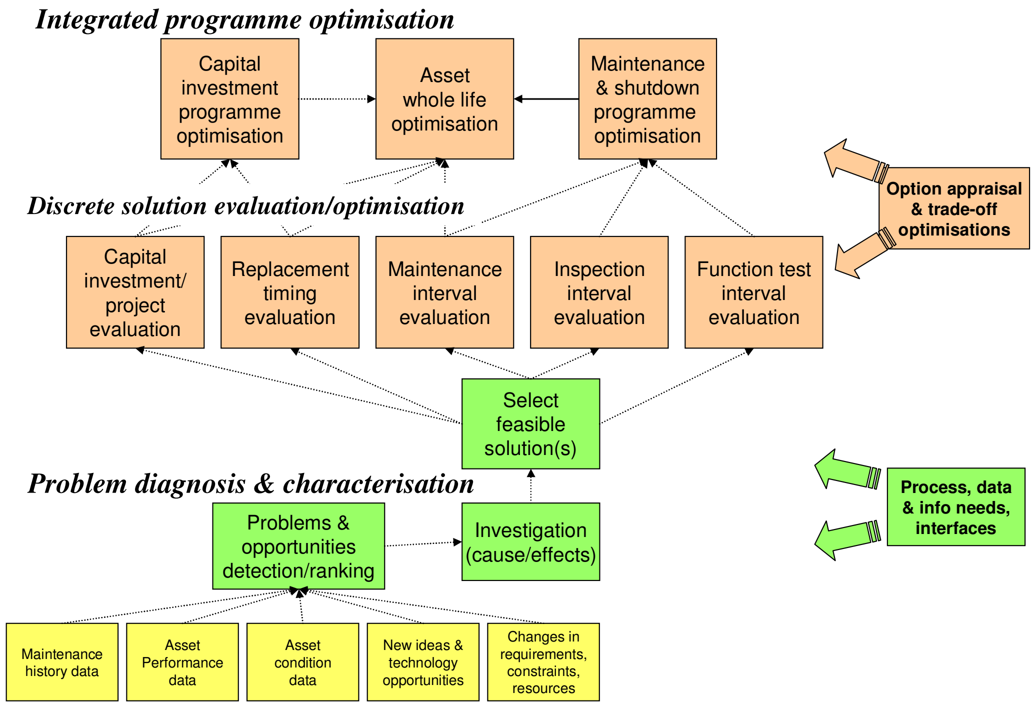


Figure 1 Technical module development requirements

Expenditure for financial year	**Internal £8k** **External £10k** **Total £18k**	**Expenditure in previous (IFI) financial years**	**Internal £62k** **External £91** **Total £153k**
Total project costs (collaborative + external + [company])	**£271k**	**Projected 2012/13 costs for National Grid**	**£0k**

Technological area and/or issue addressed by project	**Asset management, in particular decision-making in the management of mature assets.** **Asset management is a core capability for National Grid to enable optimal management of its assets across the whole life cycle. National Grid is committed to enhancing its asset management capability. It was the first utility in the world to gain BSI PAS 55 certification and is actively involved in developing asset management practice both internally and externally e.g. through leading and participation in Institute of Asset Management projects. National Grid sponsored and was an active contributor to the MACRO project and has extensive experience both developing and using asset management decision support tools.**

Type(s) of innovation involved	**Incremental**	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		10	**-2**	**12**

<table>
<tr><td>Expected benefits of project</td><td colspan="3">National Grid uses asset management to address current and future challenges and opportunities e.g. managing an ageing asset base, building a network to facilitate change in generation to meet climate change targets, maintaining the high reliability levels experienced by UK consumers, ensuring consumers get value for money whilst maintaining at acceptable levels, ensuring the network is sustainable in the future. This asset management requires sophisticated analytical assessment and balancing of costs, risks and performance.

£5 Billion in capital investment is identified to be needed in electricity transmission infrastructure in the next 5 years. Reasonable projections for the resultant savings in maintenance, capital investment (avoidance/ deferral/ improved value) and earlier adoption of high performance technologies represents a net estimated benefit to National Grid of £20-100 Million.

This project will contribute an estimated 10% of the potential benefits.</td></tr>
<tr><td>Expected timescale of project</td><td>3 years</td><td>Duration of benefit once achieved</td><td>5 Years</td></tr>
<tr><td>Probability of success</td><td>85%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£636k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="3">As above in the ‘Expected benefits of Project’ section.

The confidence level in achieving these benefits continues to rise as the project progresses – the latest field trials have all confirmed early studies: large cost & risk savings through remixing intervention options and timing. For example, London Underground recently applied prototype SALVO methods to steelwork painting strategies and track maintenance – in both cases revealing multi-million £ benefits from optimisation of asset life cycle strategies. Similarly, SASOL has recently completed two studies – obsolescence/upgrade timings for distributed control systems/instrumentation and asset replacement programme for high voltage electric motors. Again, multi-million £ benefits were identified from optimising the plans.</td></tr>
<tr><td>Project progress [Year to End of March 2013]</td><td colspan="3">The project has suffered delays – mostly due to the sponsor’s available resources but also in the cost and duration of the software development efforts. The project is now expected to launch in October 2013 (rather than end of 2012 as originally planned). The project managers, TWPL, are covering the incremental costs involved from this extension.

During 2012, the software modules were released in stages. These included Lifespan (asset replacement and life cycle costing), Maintenance, Inspection and Project Modules. National Grid has been involved with evaluating these modules.

Since the project’s inception, during TPCR4, National Grid was required (under special condition B17 of the transmission licence) to develop a series of Network Output Measures. These included a set of network replacement outputs, the primary output for which is network risk. As a result, SALVO’s emphasis on cost as an output and relative risk means that the tool is not suitable for network replacement planning.

However, the software has the potential for use as a decision support tool to develop National Grid’s life-cycle costing. Improved financial assessment in new technology/deviations in techniques and policies require a life cycle costing tool so that decisions can achieve maximum value for National Grid, in terms of understanding long term operational considerations which require detailed financial analysis. Life cycle costing has the benefits of:
- Meeting National Grid’s strategy using consistent ways of working.</td></tr>
</table>

	- Establish National Grid as using a leading asset management approach in decision making. - Provide improved decision making working towards National Grid achieving genuine value optimisation. - Ensure Whole Life Cycle Costing accurately being reflected in our decisions. - Articulating clearly narrative and drivers of decisions to the Regulator and to other stakeholders. Evaluation of SALVO as a life-cycle costing tool is currently ongoing.
Collaborative partners	Other Sponsors: Scottish Water, London Underground, SASOL 'Industrial Associates': Scottish Power, Halcrow, AMT-Sybex, IBM, Centrica, Sodexo
R&D provider	The Woodhouse Partnership Ltd, The University of Cambridge

Project title	Improved Transformer Thermal Monitoring		
Project Engineer	Gordon Wilson		
Description of project	This project will deliver an improved transformer thermal model that enables accurate ratings to be calculated. A method for determining thermal parameters for those transformers without test certificates will be developed. The project will specifically address the effects of ambient conditions, changes in cooling state and the influences of the transformer surroundings, of particular interest in built-up locations. Met Office data from a previous scheme will be used to assess the effects of 'heat-wave' conditions, of especial importance in the South-East.		
Expenditure for financial year	Internal £8k External £0k Total £8k	Expenditure in previous (IFI) financial years	Internal £8k External £124k Total £132k
Total project costs (collaborative + external + [company])	£175k	Projected 2012/13 costs for national Grid	£35k
Technological area and/or issue addressed by project	National Grid uses transformer thermal ratings for planning purposes and day-to-day operation of the transmission system. The thermal ratings use transformer models based on IEC methods that are known to have shortcomings, particularly with oil temperature behaviour and where changes of cooling state occur. National Grid is now acquiring transformers cooled only by natural circulation or by three-stage cooling and these require modifications to the existing ratings process to be modelled properly. Transformer thermal capability is calculated from known test certificate data. However, some older transformers in key locations do not have test certificate data, resulting in the use of conservative ratings that will be restrictive. The relevant thermal parameters could be determined by the application of appropriate models to the measured data for these units. An attempt to determine thermal parameters for transformers at New Cross has been made based on long-term monitoring. However, the work at New Cross has highlighted significant shortcomings in the application of existing IEC models to actual data, leading to difficulties in estimating the thermal parameters accurately. The potential influence of ambient conditions and the effects of the environment in which the transformers are installed has also been shown. Measurements of ambient conditions were taken at New Cross that have not yet been incorporated into transformer models. These data will be analysed to assess the influence of the environment on transformer ratings. A transformer with known thermal parameters (and ideally with fibre-optic temperature sensors installed) will be fully instrumented at another location to enable an accurate model of transformer thermal behaviour, as installed at site, to be developed. Since the thermal and electrical parameters will be known beforehand (unlike at New Cross), the success of various methods in obtaining these values from the logged temperatures and loading data can be assessed, for application elsewhere. Particular attention will be given to the behaviour of the oil flow which is known to be quite complex. The effects of ambient conditions can be compared with those at New Cross. The resulting thermal models		

	will be useable in the transformer rating program TRALC, and also for real-time rating estimates by the cable temperature monitor (CTM). The thermal ageing of transformer windings is governed by the detailed nature of the winding construction and oil flow rates, although average values for winding and oil temperatures can be obtained by factory test measurements. The TEFLOW program has been used for such detailed calculations in the past. It has proved valuable in the assessment of failures where the necessary detailed winding measurements can be obtained by inspection. Support will be provided to the University of Manchester in improving the TEFLOW thermal model and further developing the TEFLOW program. The existing transformer loading program TRALC is used for calculating transformer ratings. Improvements to the thermal model derived under parts of this project described above will need to be incorporated in TRALC. In addition, the electrical model in TRALC will be re-assessed for its suitability in modelling load flow in either direction (HV to LV or LV to HV) and for estimating core flux more accurately. If necessary, the existing electrical model will be improved. A new specification for TRALC v3 incorporating the required changes will be produced. The EPRI transformer loading program PTLOAD will be assessed to ensure that National Grid follows best practice in transformer rating calculations.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		15	0	15
Expected benefits of project	The provision of enhanced ratings through calculation of potential enhancements provides large cost savings for National Grid and increases flexibility in placing outages. In recent times the potential for granting enhancements has been employed in evaluating load related schemes and deferrals have been possible. In some cases it has not been possible to provide enhancements because of the lack of a test certificate, for example upratings at Ninfield and North Hyde could not be modelled and Cowley, Kingsnorth and Mannington are affected by the same transformers; there are around 100 transformers for which models cannot be produced. This project will result in a method for accurately determining the potential enhancement of such transformers allowing deferral of capital investment at a moderate cost. TRALC v2 has been revised and updated on a number of occasions since it was first developed; the software developers have suggested that further updates will become increasingly difficult (and more expensive) thus a new version will be required to allow inclusion of three stage cooling and ONAN transformers. It would also allow these transformers to be modelled correctly in the new version of CTM. System Development are supportive of the research and have produced a model showing how deferrals might be possible depending on demand growth rate at grid supply points (GSPs) and potential uprating resulting from more accurate models. Based on recent years the average number of new transformers installed for system development each year is six. Assuming relatively modest cyclic upratings and a moderate view of growth rate the potential to defer half of the annual load related transformer installations for 3 years seems reasonable. Given that many of these sites have transformers that can already be modelled a modest assumption would be that three transformers could be deferred for 3 years in the first 5 years of implementation The unit cost of a GSP transformer is			

	approximately £4m and a three year deferral would be worth £300k.		
Expected timescale of project	3 years	Duration of benefit once achieved	5 years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£78k
Potential for achieving expected benefits	Some of the development work will be carried out within CIGRE A2.38, a group that National Grid (Gordon Wilson) is already involved with. The collaborative output of this group will form a part of the deliverables and will ensure that National Grid's transformer ratings program remains state of the art. Expected benefits have been delayed owing to a number of factors and the project would have to be considered at risk of not achieving the expected benefits especially those dependent on monitoring data. An alternative method of delivering the monitoring required needs to be considered if the project is to be successful		
Project progress [Year to End of March 2013]	This project was late starting owing to a number of reasons, not the fault of the supplier and is currently delayed. A candidate transformer had been selected for enhanced monitoring to provide data for the work but has since been made redundant as a result of network reinforcement at the substation concerned. An alternative was identified. A specification for the monitoring required has been developed and instrumentation requirements have been identified and evaluated. Installation of the monitoring equipment has been delayed and an alternative route to achieve installation is required but this will necessitate a change request for additional funding. The original equipment used for monitoring optical fibres was located and appropriate connectors were obtained but upon testing the identified transformer only a fleeting result was obtained and then the signals were too weak. Further testing of optical fibres on transformers may be worth evaluation and were planned as part of another project but this has since been cancelled and may be adopted as part of this project. The deliverables of this project will likely contribute to the proposed NIC funded project MEDICI that, if successful, will start in April 2014		
Collaborative partners			
R&D provider	Southampton Dielectric consultants Doble Power Test		

<table>
<tr><th>Project title</th><th colspan="4">Transformer and system reliability</th></tr>
<tr><td>Project Engineer</td><td colspan="4">Paul Jarman</td></tr>
<tr><td>Description of project</td><td colspan="4">This project will deliver a methodology for assessing the maintenance and replacement strategies for transformers against system reliability requirements. In particular the derivation of transformer replacement priority from asset health index and perceived system criticality can be greatly refined using a detailed knowledge of transformer failure modes (common mode, sympathetic and hidden failures). The availability of such a methodology will ensure an optimum and justifiable prioritisation of transformer replacement and maintenance.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £9k
External £79k
Total £88k</td><td colspan="2">Expenditure in previous (IFI) financial years</td><td>Internal £7k
External £146
Total £153</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£240k</td><td colspan="2">Projected 2013/14 costs for national Grid</td><td>£55k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">At present the risk and criticality approach to transformer maintenance and replacement is based on a relatively crude 3 point scale of criticality and a matrix. This method may be capable of improvement if a real network model is used together with an understanding of possible interactions between failures. Generally a transformer outage is of manageable impact, but two or more simultaneous outages on certain parts of the network could have severe consequences. Identifying these situations and the sensitivity to linked failures is important for the correct and timely replacement of the most critical units. As far as can be determined there is nothing significant published on the interaction of transformer reliability and overall system reliability. One of the final parts of the transformer lifetime project which is in progress was to look at this area but it is unlikely that there will be time on this project to start this work.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>8</td><td>0</td><td>8</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Transformer replacement is worth some £20-£40M per year for many years to come, optimising this expenditure and reducing the likelihood of a costly system failure due to late replacement depends on the correct and timely identification of replacement candidates. This project will make a small but significant contribution to this process.</td></tr>
<tr><td>Expected timescale of project</td><td>4 years</td><td colspan="2">Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td>60%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£86k</td></tr>
<tr><td>Potential for</td><td colspan="4">The project will use the combined expertise of the Transformer and System</td></tr>
</table>

achieving expected benefits	**research groups at the University of Manchester. There is therefore a significant background of knowledge that will be used. The probability of making progress towards a useable failure criticality model is high. It is possible that the problem will have to be simplified to make progress. This should however still result in useful results.**
Project progress [Year to End of March 2013]	**Two students are in place and have been working on the project. Power Factory software has been used to test the capability of making reliability estimates on a test system configuration often used for benchmarking. This showed that some refinement of the reliability assessment method in Power Factory was required. This reliability method has now been developed and successfully tested. A model of the London system has been adopted and used and preliminary results have been obtained. The results show some interesting features, but work is continuing on scenario development to make the results more useful.** **Work on the transformer reliability model has produced a good paper condition based model from literature results and this is being expanded into other aspects of transformer unreliability. National Grid historical data has been used to validate the model and provide a reliability figure that can be used in the reliability calculation. Work continues on linked failure probability calculations.**
Collaborative partners	**None**
R&D provider	**University of Manchester**

Project title	Transformer Oil Passivation and Impact of Corrosive Sulphur (TOPICS)		
Project Engineer	Gordon Wilson		
Description of project	The key objective of this project is to reduce the risk of transformer failure and unreliability resulting from corrosive sulphur in oil. This key objective will be met by: • Better understanding of the mechanism by which copper sulphide failures occur and the effectiveness of passivation. • Fully understanding the effects, both chemical and electrical, of passivation on transformer insulation performance. • Investigating the reasons for silver corrosion in tap changers and to formulate monitoring/assessment strategies in order to provide a measure of asset health.		
Expenditure for financial year 11/12	Internal £10k External £55k Total £64k	Expenditure in previous (IFI) financial years	Internal £5k External £137k Total £142k
Total project costs (collaborative + external + [company])	£234k	Projected 2013/14 costs for national Grid	£129k
Technological area and/or issue addressed by project	Formation of corrosive sulphur in oil and subsequent copper sulphide deposition in paper has led to a number of large transformer failures worldwide. It was the cause of the failure of a large power transformer in 2007 and other transformers will be removed from the system early because the problem is believed to be advanced. Part of the complex process leading to transformer failure involves the mobilisation of copper containing material into the paper insulation surrounding the windings, which is known to be influenced by the presence of corrosive sulphur species in the oil, and extreme operating conditions. Although there have been many attempts to understand the mechanism better by which formation of copper sulphide occurs none have yet been conclusive. They have not led to sufficient understanding to allow diagnosis of the problem without inspection and better mitigation methods may still arise if the mechanism is better understood. Laboratory studies of the mechanism have largely focussed on the thermal aspects of the mechanism and also the interactions between oil, paper and the surface of copper conductors. This study will use facilities in the Tony Davies High Voltage Laboratory at the University of Southampton to evaluate corrosive sulphur formation in covered conductor samples that are carrying current and will attempt to recreate more accurately the conditions in a transformer in order to better replicate the mode of failure witnessed in transformers i.e. turn to turn failure. The mechanism by which copper sulphide migrates through the paper and the possible interaction of mobile copper ions and/or complexes in the oil will also be investigated. One mitigation strategy employed by transformer owners, including National Grid through OESB 9/08, is to protect the copper surface of the		

windings by the addition of chemical passivators, such as Irgamet™ 39, to the oil. Passivators are designed to interact with the copper surface to provide a protective barrier and reduce corrosion.

The long-term effects of passivation as a remedial strategy to keep transformers in operation are poorly understood and largely informed by experience over a limited number of years rather than laboratory studies that consider the potential chemical reactions. The effectiveness with which copper surfaces are coated with passivator following retrospective addition of Irgamet ™ 39 to a transformer has not been studied.

In this study we will investigate, and gain a greater understanding of, the chemical effects of passivation through laboratory based experiments and visits into the field. The proposed work will involve collaboration between the School of Chemistry at the University of Southampton and the Tony Davies High Voltage Laboratory, building upon a highly effective collaborative relationship developed during the recently completed IFI-funded feasibility study on corrosion in the gas phase. Questions that are to be addressed during this study include.

- What is the long term stability of passivator on the surface of copper?
- Is it necessary to add more passivator when it is consumed in the oil?
- How might one analyse the surface of copper for the presence of passivator?
- Can this be used on scrapped transformers to investigate whether the passivator gets through all the paper insulation to where it is needed?
- If passivator works by coating the surface of copper, which has a fixed surface area, why have others reported that more is required when you have a higher concentration of Dibenzyl Disulfide (DBDS)?

To address the questions above, it is planned to develop chemical tests using a variety of analytical methods to study and quantify the passivator (e.g. Irgamet™ 39) on copper strips in heated oil over time. Irgamet™ 39 reacts with the copper surface to provide a “protective coating” of benzotriazole on the surface, which can be analyzed using a variety of surface techniques. For example, SEM EDX can be used to monitor surface elemental composition (C, O, S and N), or some more sophisticated surface spectroscopic techniques such as surface Raman spectroscopy, TOF/SIMS to directly probe the nature of the chemical species bound to the surface. Oils designated as “corrosive” and “non corrosive” would be studied, and the effect of the passivator assessed both at the copper surface and through mobilisation of copper into oil. The effect of temperature and time on the passivated copper will be studied. Techniques such as Gas Chromatography-Mass Spectrometry (GCMS) and x-ray fluorescence spectroscopy are established in Southampton, and will be employed for oil analysis. The simultaneous application of techniques to monitor the condition of the oil and the copper surface will be powerful, and allow a more detailed understanding of the interactions of passivator, copper and DBDS (paper wrapping may also be added to the study at any point).

Irgamet™ 39 is itself a reactive species designed to be soluble in transformer oil, which liberates a benzotriazole derivative (the active passivator molecule) at the copper surface. There are two byproducts from

	this process, namely formaldehyde and an amine, both of which may have an impact on the properties of the oil. The effect of these compounds may not emerge until additional amounts of passivator have been added. The effects of these compounds may also be studied using the vial tests. Samples of paper-wrapped windings from failed transformers (provided by National Grid) will also undergo passivation tests, to assess how effective passivation is on "at risk" plant. In parallel with developing understanding of the chemistry involved in the addition of passivators to transformer oil, studies will be undertaken to determine its effect on the thermal/mechanical/electrical properties of the paper/oil insulation system over time. In particular it is necessary to establish whether the addition of passivation effect interturn losses or cause increased operating temperatures. The work on passivation will involve close collaboration between two PhD students, one based within Chemistry and the other in the Tony Davies Laboratory. Oil reclamation of transformer oil through heated clay columns has been used as a remedial measure when corrosive oil is detected and was successfully demonstrated as an effective technique in a previous IFI project. However, through that study and following regeneration of oxidised oil in recent years there has been undesirable corrosion of silver in tap changers (OESB 4/09 refers). There is also some evidence of increased gassing in some transformers using reclaimed oil. It is suspected that the reclamation process is itself adversely affecting the oil, and possibly even introduces corrosive substances such as elemental sulphur. During the first 12 months of this project a Research Assistant, predominantly based in Chemistry will also consider the issue of this silver corrosion in tap-changers. The aim of this study is to gain an improved understanding of how the reclamation process affects the chemical composition of the oil and how the amount of specific components such as elemental sulphur, DBDS and passivators are influenced by the reclamation process. Ultimately, an enhanced understanding of the reclamation process should provide methods to monitor oil quality and provide methods to remove corrosive substances from the oil. The main objectives for the study will be: • To develop methods to ensure that any identified corrosive substance such as elemental sulphur is removed from the oil during reclamation. • To ensure that the reclamation process is not introducing specific corrosive substances. In order to support these main aims, we will need to identify specific chemical components present in the oil that cause silver corrosion. We will develop and apply suitable tests and analytical methods to detect silver corrosion and specific chemical components in the oil that are of interest, such as elemental sulphur. Part of the research will focus on the clay, and how different batches of clay can influence the reclamation. This will involve analysis of fresh clay, and clay that has been previously used in reclamation to see if residual sulphur remains in the clay after burning off. This may ultimately allow differentiation between "good" and unsuitable clays.

Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score

		8	-2	10
Expected benefits of project	A large proportion of National Grid's transformers are affected by corrosive sulphur to some extent because of the long period during which the problem oil was available and the relatively low concentration of corrosive molecules required to make an oil corrosive. There are 31 transformers considered to be at high risk because they are of a design which means they operate at higher temperatures than typical transformers. From this group, Lackenby SGT6 and Rochdale SGT5 are scheduled for replacement in 2011 and 2012 respectively because they are believed to be at highest risk of corrosive sulphur related failure. The results of the scrapping of these transformers will be part of the proposed project. The information gained from the scrapping of these transformers will inform the future strategy for other transformers considered to be at greatest risk of reduced asset life or failure because of corrosive sulphur and their individual operating conditions. Due to evidence of localised ageing or heavy loading seven of the transformers are at Asset Health Index 2a or 2b the replacement cost of these assets is approximately £28m. Ensuring that mitigation strategies are effective will provide some protection against early asset write-off. Most immediately, understanding how the copper sulphide formation is developing in the two transformers already scheduled for replacement will impact directly on the decision on whether to replace Drakelow SGT5 and Ferrybridge SGT1A or whether they can be left in service for another 5+ years (approximate deferred cost of £100k pa per transformer). It should not be forgotten that the transformers may need to be replaced early because of the thermal design limitations even if copper sulphide formation can be prevented. Around 175 other transformers are known to contain oil with the potential to become corrosive because of their age and the remainder of the population (around 700 transformers) are being tested for potential corrosivity resulting from top-ups and maintenance activity. The mitigation strategy for these transformers has been to add passivator to the oil on the basis that this will coat all copper surfaces and prevent catalytic conversion of DBDS and other sulphur molecules into a more reactive form. Although this is the most widely used mitigation strategy its effectiveness is not fully known and whether there is a need to add more passivator after it has been consumed is open to question. The effectiveness of National Grid's mitigation strategy for transformers at risk from corrosive sulphur formation will be evaluated and improved through better understanding of the mechanism of copper sulphide formation and passivation of copper surfaces. The project sets out to achieve the following business benefits: National Grid will be able to better understand and potentially monitor the condition of transformers that are believed to be susceptible to corrosive sulphur Passivation can be used appropriately as a mitigation strategy and with knowledge of the likely long term effect on transformer performance. Better mitigation strategies should lead to a reduction of early asset write offs and avoidance of failures.			
Expected timescale of project	3 Years	Duration of benefit once achieved	5 years	

Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**-£266k**
Potential for achieving expected benefits	**This proposal seeks to build on a successful record of work relating to oil/paper insulation systems at the University of Southampton.** **The Tony Davies High Voltage Laboratory has over 20 years of experience of using insulation oils in high voltage testing and has observed changes in the characteristics of oil as a function of testing regime.** **Previous National Grid funded work relating to the ageing behaviour of dodecylbenzene (DDB) cable oil systems is world leading and has led to a complete chemical description of the process, the identification of key ageing indicators and the determination of end of life criteria.** **The Chemistry department at the University of Southampton have experience and understating of the related chemistry, supported by a wide range of analytical techniques, and through the IFI project "CorrS" have provided National Grid with confirmation of the role of DBDS in the mechanisms that lead to the production of corrosive sulphur.** **Staff at the University of Southampton have provided forensic support and services to utilities worldwide and have carried out numerous major fault inquiries and investigations.** **Although it is difficult to extrapolate performance measures and experience, the track record outlined above leads to the conclusion that it is highly likely that this group will be able to:** • **Induce the effects of addition of passivators in the laboratory.** • **Apply appropriate techniques to characterize these.** • **Relate observed chemical to changes in key electrical properties.** • **Identify appropriate routes to improve transformer asset health.** **Despite the involvement of novel approaches to the understanding of the corrosive sulphur problem and the diligence of the student involved there remains a reasonable risk that identification of the progression of copper sulphide deposition in active transformers will not be possible through non-destructive means.** **Current progress suggests that the highest likelihood of success will be in understanding the effectiveness of passivator as mitigation of copper sulphide formation and migration.** **Work on silver corrosion continues and there is a moderate to high chance of success but there is a risk that more time may be needed to achieve both aims – understanding the mechanism and development of a technique to remove the corrosion from affected transformers. Silver corrosion when regeneration has not been performed may be an additional area of study required.**		
Project progress [Year to End of March 2013]	**Both PhD students are now in place and performing at a high level and the research associate working on silver corrosion is around half way through the study.** **In the area of copper sulphide the progress is more advanced as the student started earlier. Following completion of a comprehensive literature survey and familiarisation with the techniques likely to be involved in the project, sample preparation, which was a particular**		

	challenge, and construction of a test rig has been a significant focus in the last 12 months. Frequency Dielectric Spectroscopy (FDS) is showing some promise in detection of copper sulphide deposition on paper but there are known problems with the interference of water which dominates the spectrum. Differentiating the copper sulphide response will be a key focus and the offer of FDS data support from Budapest University of Technology and Economics at the recent IEEE Electrical Insulation Conference is likely to help in this aspect. As part of this study the use of XRF (X-Ray Fluorescence) as a means to track the changes of sulphur content in oil when copper sulphide deposits are being formed has been explored and contributed to CIGRE WG A2.40. The chemistry student investigating passivation started later but has benefited from the presence of the electrical engineering student and previous experience studying corrosive sulphur at SEA Marconi laboratories in Italy. The study of passivator on the surface of copper using X-Ray Photon Spectroscopy is very promising but further work is required in this area before moving to samples from transformers. A number of techniques have been evaluated for the study of silver corrosion following regeneration including XRF, GC-MS (gas chromatography coupled to mass spectrometry) and SEM-EDX (scanning electron microscopy with electron dispersive X-Ray analysis). XRF is the most promising for total sulphur and some species may be identified by GC-MS. The problem of introducing corrosion to transformers during regeneration appears to have been solved but further work is required on the study of different clays to understand why some produce more corrosive sulphur than others. Although elemental sulphur is suspected to be the main corrosive element further studies are required to confirm there are no others before remediation techniques can be identified. Two papers based on this work were published and presented at the recent IEEE EIC conference in Ottawa with some good feedback, especially on copper sulphide activity. These will be available through IEEE XPlore. Papers have also been submitted to IEEE CEIDP (Conference on Electrical Insulation and Dielectric Phenomena) for later in 2013. The Oil Management Unit has supplied numerous samples during regeneration activity to aid this work.
Collaborative partners	Doble are supporting the work through access to samples from scrapped transformers
R&D provider	University of Southampton

Project title	Voltage Optimiser Pilot				
Project Engineer	John Fitch/Jude Robinson				
Description of project	This Project is to pilot the installation of a Voltage Optimiser at Rayleigh substation to evaluate the claimed benefits of energy savings on electricity consumption by reducing the incoming LVAC supply voltage by a fixed amount into the site LVAC board. There are also additional benefits which are due to the reduced heating and insulation stresses on the substation connected equipment, which should improve asset life and reliability.				
Expenditure for financial year 11/12	Internal £5k External £43k Total £47k		Expenditure in previous (IFI) financial years	Internal £7k External £0k Total £7k	
Total project costs (collaborative + external + [company])	£81k		Projected 2012/13 costs	£27k	
Technological area and/or issue addressed by project	Introducing a voltage reduction system into incoming supplies is common practice for office and industrial installations and large savings in energy consumption are claimed. This pilot is to install an EMS Powerstar Voltage Optimiser on one of the incoming LVAC supplies at Rayleigh substation and to carry out an evaluation of the benefits and any deployment issues over a period of 1 year. There are 2 proposed options with different potential benefits: ■ 1 x 500kVA unit on one transformer, cost £27.5k inc. installation ■ 2 x 500kVA units, 1 on each transformer, cost £54.75k. Inc. installation This solution has already been described in a Strategy Brief,				
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score	
		10	-6	16	
Expected benefits of project	The benefits are reduced energy consumption on energy metered sites and potentially improved asset life of LVAC connected equipment, due to reduced heating effects and insulation stresses. There will also be energy savings which will result in financial and emission savings benefiting National Grid. EMS Powerstar has no moving parts and therefore minimum maintenance costs and procedures. A desktop study on a typical site concluded:- ■ Consumption 01/08/09 – 31/07/10 = 1,074,382kWh ■ Site voltage: Min: 233.6, Max 241.9, Ave: 237.8 ■ Potential to reduce site voltage by 15V				

	■ Resulting in a percentage saving of kWh = 9.4% of kWh (100% guaranteed) ■ kWh savings 100,992kWh, Tonnes of Carbon Dioxide saved 55.2 tCO_2 If the desktop study is representative, there is potential savings of £2,760 saving in $C0_2$ per year, per site (cost of CO_2 @£50 / tonne as per internal sustainability guidelines) and a saving of £6,000 in energy consumption (assuming 6p per kwh), resulting in a saving of approximately £9,000 per site. If this was applied to all 337 substations nationwide and they were all similar, it could result in a year on year saving of approximately £3m per year.		
Expected timescale of project	2 years	Duration of benefit once achieved	5 years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£5k
Potential for achieving expected benefits	This project carries little financial risk.. The level of susses will be agreed at the end of the project and form part of the commercial terms with EMS Powerstar. It is however expected that the claimed benefits will be achieved, due to the wide experience of installed installations worldwide. The main concern is on the impact on LVAC equipment unique to National Grid and this will be part of the evaluation. The likelihood of success is therefore considered to be very high.		
Project progress [Year to End of March 2013]	It was initially planned to install the Voltage Optimiser at Rayleigh Substation as described in the original proposal. A great deal of design and application work was carried out with this site as the planned location. However it was found during a site meeting that it would not be possible to get an outage on the LVAC board, due to switchgear limitations on the incoming circuits, and another site had to be selected. To overcome the LVAC board outage issues it was decided to align the installation with the LVAC board replacement programme. The project is now aiming to install the Voltage Optimiser during 3Q 2013 as part of the LVAC board replacement at Capenhurst. Energy Metering information has been collected and a site meeting taken place for finalising design and application issues. The change of target site and the change in size of the Voltage Optimiser required for Capenhurst has delayed the completion of the project and required a budget change control. Work is proceeding to order the required size unit for the site and put in place all necessary design, installation and commissioning documentation required for the project.		
Collaborative partners			
R&D provider	EMS – Powerstar		

Project title	In-situ remediation of OHL Tower Steelwork		
Project Engineer	David Smith		
Description of project	This project will consider a range of technologies, as employed in other industries, for the remediation of structural steelwork. It will assess the suitability of these technologies for use on lattice steel structures carrying live 275kV and 400kV conductors. The 3 key deliverables of this project will be: • The adaptation of recognised methodologies (techniques for cleaning the steel and combinations of products for re-coating it) for remediation of structural steelwork and the demonstration of the effectiveness of this solution (through trials and accelerated weathering tests) for use on National Grid's overhead line (OHL) towers during outage & non-outage conditions. • The creation of a procedure/manual to support ongoing implementation of the techniques developed. • Development of a training package to ensure consistent recording & communication the condition of the steelwork prior to and after remediation.		
Expenditure for financial year 11/12	Internal £39k External £70k Total £109k	Expenditure in previous (IFI) financial years	Internal £64k External £18k Total £82k
Total project costs (collaborative + external + [company])	£191k	Projected 2013/14 costs for National Grid	£0k
Technological area and/or issue addressed by project	National Grid is in the process of investing over £150m on the refurbishment of OHL lattice steelwork towers. Current asset policies require the replacement of steelwork identified as Grade 4 (in accordance with TG4) or worse – and this policy is being reviewed by a steelwork strategy team. One of the outputs of this team has been the identification of a need to consider the in-situ remediation of Grade 4 tower steelwork on main structural members as the volumes of steelwork involved are extensive and current methodologies require several circuit outages or a lengthy double circuit outage to complete the works. Faced with a growing capital programme and the need to minimise circuit outages, it is necessary to consider alternative methodologies to resolve this problem. The key issues to be addressed by this project are therefore the identification, recording and remediation of Grade 4 steelwork on primary structural members of National Grid's lattice steel towers under outage & non-outage conditions.		

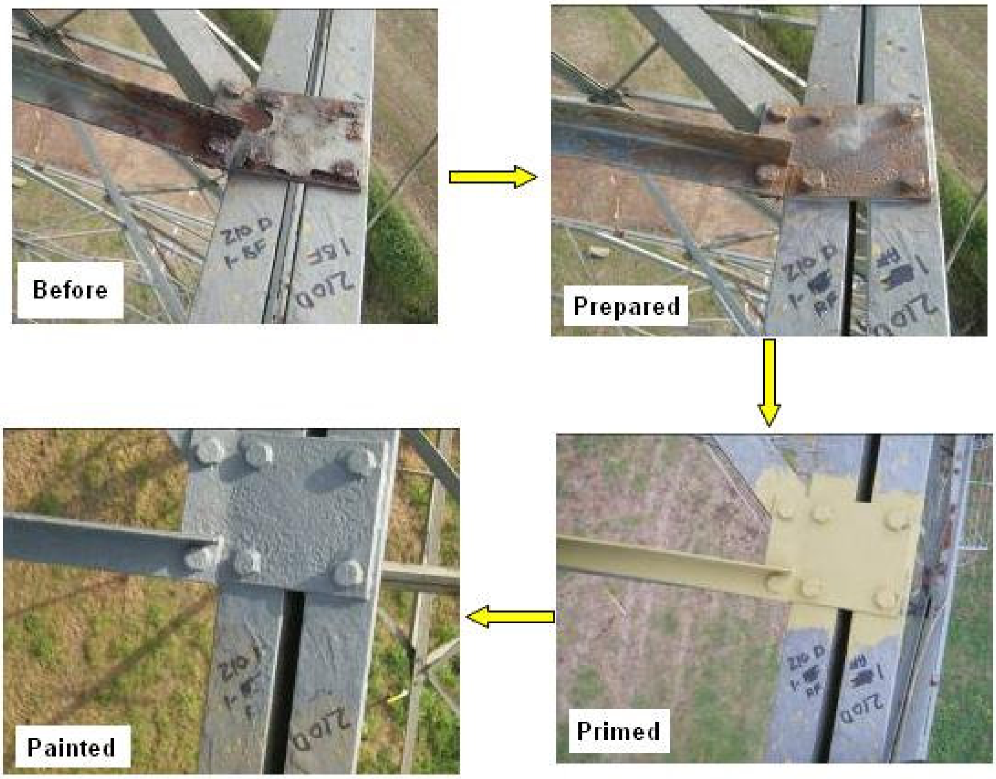
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		12	-2	14

Expected benefits of project	The most significant benefits to be delivered to the business by this project are: • The minimisation of circuit outage time required for the remediation of tower steelwork. It will be possible to undertake the majority of the steelwork remediation under non-outage conditions, with only essential cross-arm works to be completed during the outage. When this is compared to the current methodology (circuit 1 outage to transfer circuit to temporary towers, followed by circuit 2 outage to dismantle tower, replace steelwork & re-erect; followed by a final circuit 1 outage to transfer back to refurbished tower) it can be seen that this will be a much simpler process, allowing the utilization of more staff over the non-outage season. • The reduction in cost per tower for the remediation. In the majority of cases there will be no requirement to transfer circuits to temporary towers resulting in a simpler, faster remediation process. The unit cost element of this will be established during the project, once a remediation methodology has been established and assessed, but is estimated to be up to £30m against a predicted budget of £150m.		
Expected timescale of project	2 years	Duration of benefit once achieved	8 years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£1,632k
Potential for achieving expected benefits	The likelihood of success is believed to be high, although this will be verified as the project progresses, initially a medium likelihood of success is estimated against the full benefit. The technologies to be assessed are used daily to resolve similar problems in other industries. The adaptation process will be undertaken by specialists in tower remediation, supported by other industry specialists in corrosion & remediation techniques. This will bring the right knowledge bases together to identify the right methodologies to be applied in any given circumstance. This will allow us to translate the results of this assessment into a repeatable process and identify the appropriate industry standard training for all personnel who will be involved in this type of work. The use of C3 Global in the development of a methodology to record & report the condition of tower steelwork builds upon their expertise in the delivery of the SAM (Strategic Asset Management) platform. The intention of the project would be to utilize this platform as the backbone of the reporting process, feeding back asset data in a manner similar to the other data sets being currently & successfully transmitted.		
Project progress [Year to End of March 2013]	The project has progressed well, though a little slower than originally hoped. Initial trials of the techniques have been encouraging and a full scale trial on the Cellarhead – Daines/Macclesfield scheme took place early in the 2012 outage season. The results were good. Three new documents have been produced:- TS 3.4.31: Specification for Steelwork Inspection and Condition Assessment of Overhead Line Towers. PS(T) 102: Overhead Line Tower Steelwork Replacement draft. TS 3.4.34: Specification for Overhead Line Tower Spot Surface Preparation Prior to Painting draft.		

These were presented within National Grid. TS 3.4.31 was accepted with minor modifications. There was much discussion regarding the other two. These will be the subject of a further 12 months trial (on 4ZO, ZK, ZX & other routes on a scheme specific basis) after which, if successful, they will be fully adopted and issued. The Tower Painting Contractors are using these documents now.

The original intention was to develop a database; this turned out to be too expensive to do under the R&D project. Mark Simmons is developing a process of zonal condition assessment for the top of an L2 tower. Once this is done, it will be given to a software company for them to replicate this over the rest of National Grid's portfolio of tower types.

This project is now closed, however it has highlighted other opportunities for future work to address.



Collaborative partners	
R&D provider	Capcis, C3 Global, Electricity Alliance East, Electricity Alliance West, National Grid Tower Painting Contractors (CLC, PDC & Fountains)

Project title	Alternative Differential Unit Protection for Cable only and Cable & OHL hybrid installation by using non conventional current sensors i.e. Rogowski coil.		
Project Engineer	Tahasin Rahman and John Fitch		
Description of project	This R&D Project aims : To evaluate the practicability, reliability and benefits of implementing alternative non conventional current sensors (i.e. Rogowski coil) based differential unit protection for Cable systems (i.e. Cable only and Cable & overhead line (OHL) hybrid installations) over conventional Current Transformer (CT) based protection. To carry out the preliminary evaluation a pilot installation is recommended on Pitsmoor-Wincobank cable circuit in April 2012 as a monitoring unit. To determine the system's suitability to be utilised as Emergency Return to Service (ERTS) system. This will help to formulate a technical and operational knowledge base for Non Conventional Instrument Transformer (NCIT) protection systems which could lead to evaluation of future technical and procurement strategy to deploy as replacement and/or new cable system protection.		
Expenditure for financial year 11/12	Internal £22k External £71k Total £93k	Expenditure in previous (IFI) financial years	Internal £5k External £1k Total £6k
Total project costs (collaborative + external + [company])	£100k	Projected 2013/14 costs for National Grid	£0k
Technological area and/or issue addressed by project	Public perception towards OHLs and limitations on rights-of -ways in populated areas could potentially lead to an increase in construction of cable only and cable & OHL hybrid circuits in future. This situation presents a unique challenge for cable protection systems especially on the hybrid one as protection systems must differentiate between cable and OHL faults to ensure the greater reliability of the power system. Current practice in National Grid is to implement two main unit protection schemes sourced from two different suppliers by using conventional CTs for 275kV and 400kV cable systems. However, CT installation and maintenance on cable circuits is immensely cumbersome due to bulk structure of CTs and space constraints associated with cable tunnels and trenches. Moreover, CTs on cable circuits are subject to a high magnitude of charging/discharging current during switching on and off, a condition which could lead to potential CT core saturation and mal-operation of the protection relays. For green field application these constraints may be addressed by an appropriate design solution; however on refurbished circuits especially where part of the OHL circuit is undergrounded by using cables, it becomes challenging to achieve the prescribed selectivity and security with the conventional CT based protection scheme. In addition, to increase the operational reliability and reduce down time it is imperative to detect and discriminate transient faults i.e. lightning strikes on OHLs of hybrid systems to enable the Delay Auto Re-close as		

	stated in TS 3.24.7 and PS (T) 10. Through work with CIGRE and contacts with other utilities, an alternative non conventional current sensor i.e. Rogoswki coil base cable protection system by Cooper Power Systems has been identified as a potentially ideal solution which could offer greater operational, safety, and construction benefits over conventional protection systems due to the following features : Linearity and no saturation even at high fault currents and magnetising inrush reducing the likelihood of protection mal operation. This characteristic could also be used for monitoring and profiling of insulation degradation which could lead to better asset management practice. Light weight and compact size to address the space constraint issue. Increased safety as opening secondary wiring during operation does not result in hazardous voltages. Installation does not require opening of the primary conductors owing to the splitcore design which could reduce outage time for installation and hence has the potentiality to be deployed as ERTS system. Transmission Operator in Portugal, Rede Eléctrica Nacional (REN) is trialling and installing this solution for 220kV power cable systems including hybrid of cable & OHL since May 2010. They published a CIGRE paper titled “Experiences with Protection of Combined Overhead Line/Cable Circuits based on Non-Conventional Current Sensors” at Study Committee B5 Colloquium on September 2011. Their positive experiences and intrinsic benefits of this solution over conventional system have given greater confidence to National Grid to trial a pilot installation and, if successful subsequently, adopt a solution to meet UK transmission requirement. This could offer greater asset management benefits in the longer term, especially when managed and supported by well trained internal staff.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		6	-4	10
Expected benefits of project	The output from this project if successful will lead to adoption of the system for the UK transmission system and feed into future technical and procurement strategy. The benefits will include the following: - • Development of new Cable Protection Strategy and Policy using NCIT based protection. • Standardised plant interface and “one off” standard solution. CAPEX savings for budgetary comparison with traditional approach: • Installed cost of 400kV single phase CT is £50k = £300k for 2 x 3phase sets. • Traditional two ended NICAP installed Feeder Protection Panel typically £500k. Total cost is approx £800k. • The estimated commercial cost for this equipment is approx £200k which is 25% cost of the traditional approach. OPEX savings (training internal staff and reducing PDSA cost. Also, the equipment is delivered with 10years warranty). Reduced system access for extensions and future replacement will			

	increase personnel safety. (No risk of hazardous voltage when the secondary wires are opened in-service inadvertently). Increase system reliability and reduce down-time.		
Expected timescale of project	1 year	Duration of benefit once achieved	5 year
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£30k
Potential for achieving expected benefits	This project will collaborate closely with the National Grid and external resource (Cooper Power Systems and REN) pooled for adoption of the solution on the UK Transmission system. The likelihood of success is high due to positive experience of REN with the similar installation.		
Project progress [Year to End of March 2013]	The Project team was formed and the 1st project inaugural meeting was held with Cooper Power in December 2011. Meetings were then held with Maintenance Deliver Electricity (MDE), Construction and Cooper Power Systems to establish any technical issues related to installation and system interfacing. The Rogowski Coils and interface units were designed and procured for installation on the selected Pitsmoor-Wincobanck cable circuit. The output from the Rogowski Coils feed a compatible Unit Protection solution also procured from Cooper Power Systems. These relays communicate over the existing OPTEL network via suitable interfacing units. It is planned that the relays can be remotely accessed when remote access, via RAMM, is in place. The Rogowski coils were designed specifically to be easy to install on the cable sealing ends at each end of the circuit, using split cores to avoid opening the primary circuit conductor. Short cross site cables from the Rogowski coils to the protection relays in the relay room were run by a cable contractor. The rest of the installation and commissioning work was carried out by site engineers and fitters with some support from Cooper Power Systems during commissioning. The project benefited greatly from this detailed involvement. The protection system was successfully commissioned in May 2012 and remains in service as a “piggy back” trial for a two year period. Regular monitoring of the protection records and communications performance is in place. Analysis of the protection records demonstrated the stability of the relays both during through fault and on load condition. Since installation over a year ago, no inadvertent operation has been recorded. Following successful commissioning “lessons learnt” and Whole Life Value reviews were carried out to support the development of future implementation strategy. A joint paper titling “Relay Protection Solutions based on Non-Conventional Current Sensors in Actual Industrial/Utility Applications” has been written by Cooper Power Systems, National Grid and REN covering the application and experiences of Rogowski Coil technology in the UK and Portugal. This will be presented at the CIGRE B5 colloquium in August 2013. A final report on project progress to be published by June 2014.		
Collaborative partners			

R&D provider	**Cooper Power Systems, USA**

Project title	Wireless condition monitoring sensors with integrated diagnostics		
Project Engineer	Carl Johnstone, Ian Kerr		
Description of project	– A low-cost, readily distributed diagnostic system architecture suitable for operating wirelessly within a substation. – A report detailing the feasibility and expected functionality of fully autonomous wireless sensors deployed in a range of environments when integrated with energy harvesting devices. – Capability for integrating the technology within the SAM 'Strategic Asset Management' system' to provide real-time diagnostics (e.g. partial discharge (PD), environmental) to monitoring engineers. – A technology demonstrator based upon a low-power partial wireless PD detector and diagnostics package that can be used for PD identification.		
Expenditure for financial year 12/13	Internal £5k External £21k Total £26k	Expenditure in previous (IFI) financial years	Internal £3k External £76k Total £79k
Total project costs (collaborative + external + [company])	£149k	Projected 2012/13 costs	£46k
Technological area and/or issue addressed by project	Condition monitoring plays an increasingly important role in asset management and diagnostics for high-value equipment. New technology and advances in sensing capabilities enable the understanding of more about the asset and thus enable optimal maintenance decisions (e.g. maintain on condition). Minimising the requirements for installation and maintenance of these sensors, and removing the need for cables and batteries are the key aspects of the desirable "fit and forget" functionality. Existing approaches to substation diagnostics typically involve mains-tethered instrumentation for data acquisition. It is prohibitively expensive to roll out this type of scheme widely due to cost and cabling constraints, which inevitably leaves gaps in condition monitoring coverage that should ideally be filled. In addition, diagnostic systems have become significant assets in themselves, requiring trained personnel to operate them. This approach adds additional complexity to the task of a monitoring engineer, whose primary concern must be the operational state of plant rather than the intricacies of a diagnostic system. Therefore, a non-obtrusive, integrated approach to diagnostics should be followed. Recent developments in miniaturisation of digital electronic devices have fuelled the development of wireless sensor network technology. These networks are made up of a number of discrete sensor nodes, which integrate processing, sampling, storage and communications capabilities. By taking advantage of this technology, wireless diagnostic sensors have the potential to increase condition monitoring coverage without the need for cross-site cabling, simplifying deployment and reducing costs.		

	Through identifying general requirements for wireless condition monitoring systems, a modular approach could be defined for a multitude of sensors to be attached to the same underlying platform (for instance: radio frequency (RF), ultrasonic and thermal). In addition to sensing, wireless sensors such as this with suitable analytical capabilities can also support a level of on-board defect diagnosis. By diagnosing defects on-sensor, the volume of monitoring data can be drastically reduced at source so that only pertinent defect information is transmitted to monitoring engineers. This reduces the burden of transmitting data back to corporate networks, increasing system scalability and minimising the requirement for wideband communications links. An initial laboratory study into this type of approach, targeted at PD monitoring, has resulted in a promising new diagnostic technique built upon wireless sensor technology. This method has demonstrated detection and basic classification capabilities and, based on the knowledge gained from this study, implementing the ultra high frequency (UHF) technique on a wireless sensor node has been recognised as feasible. Based upon this prior work, a wireless condition monitoring platform technology demonstrator could be created using partial discharge detection and diagnosis as a reference application. Sensors of this type may also be integrated with an energy harvesting module to self-power the device from the ambient electromagnetic fields that are present within a substation. This will reduce the need for battery replacement and related maintenance. National Grid has already pioneered the funding of research into electromagnetic energy harvesting within substations, which would dovetail with this research into low-power sensors.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		10	0	10
Expected benefits of project	The aim of this project is to prove the architecture and methodology underpinning a new approach to condition monitoring. This is likely to produce medium-term cost benefits, as National Grid may be able to set new industry standards for low cost wireless condition monitoring sensors in the future. As the underlying technology matures, its deployment will allow National Grid to: – Increase the coverage of condition monitoring systems through cost-effective deployments to lower-value assets; – Allow the use of defect corroboration techniques among a larger pool of sensors to mitigate diagnostic errors that may result from sensor failure; – Implement additional sensing applications by applying other sensor types to the diagnostic architecture; – Provide better resolution of plant health through increased sensor coverage. All of these benefits will be at a reduced cost compared with conventional systems, in gas insulated switchgear and power transformers, for example.			

Expected timescale of project	**2 years**	**Duration of benefit once achieved**	**5 years**
Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**-£110K**
Potential for achieving expected benefits	**It is proposed that the platform be built upon standards-based wireless technology specifically designed for industrial environments. This technology is well documented and supported, and has already seen deployments within the oil and gas industry. Using this as a base mitigates significant risk from the project as the technology has already been proven in harsh environments.** **For the technical demonstrator, success of this project can be measured in terms of the proposed device's ability to capture and identify partial discharges, to diagnose defects, and to present appropriate diagnostic information to monitoring engineers.** **The principles of the proposed demonstrator's approach to low-power PD diagnostics have previously been demonstrated in the laboratory – this work was recently published in a leading journal[1]. Based upon the knowledge gained from this study, it is highly likely that the UHF method may be implemented in a similar fashion.** **Significant previous work has gone into developing diagnostic methods for UHF PD data classification, including data-driven and knowledge-based techniques. These same techniques may be applied in a low-power context, depending on whether their requirements match the capabilities of the underlying sensor node hardware. Executing data-driven techniques has been shown to be feasible with existing sensor network devices, and as the capabilities of sensor nodes continue to increase, it is highly likely that even if established diagnostic methods cannot currently run on sensor node hardware, they will in the near future.** **A fully functional technical demonstrator could definitely be integrated with the National Grid SAM system. An agent-based approach to building condition monitoring architectures has been proven to simplify the integration of discrete systems; this approach could be reused in this instance.**		
Project progress [Year to End of March 2013]	**The original goals were to investigate the state-of-the-art in industrial wireless sensor network (WSN) protocols for substation condition monitoring apps, looking at a cheap, low-power PD monitor as an example application.** **The main outcomes so far are:** • **The ISA100.11a wireless sensor network standard is the strongest candidate to underpin such a system. It has a lot of industry support in the oil and gas sector, and from a theoretical standpoint there are several studies in the literature on its various components that support its use in power system environments. However, it is a relatively new standard so it needs further field**		

[1] P. C. Baker, S. D. J. McArthur, M. D. Judd. A Frequency-Based RF Partial Discharge Detector for Low-Power Wireless Sensing. *Dielectrics and Electrical Insulation, IEEE Transactions on.* Vol. 17, Issue 1, pp. 133-140, February 2010

testing.

- A parallel wireless monitoring system has been deployed into the university microgrid laboratory to prove the concept of integrating an industrial WSN with a substation computer and SCADA system, the results of which are in the process of being written up. The microgrid ISA100.11a laboratory deployment has been tied into the lab SCADA system, demonstrating how this is carried out in practice. The technical aspects of the system have been fully documented, and an IEEE Transactions paper is nearing completion which documents its achievements.
- ISA100.11 equipment from Nivis LLC has been used which has required more development work than expected to get up and running. A hardware and software platform for working with Nivis radios using off-the-shelf microcontrollers and sensors has been developed, and it has been signed off for release under MIT and Creative Commons licences which means that other university projects can work with it and develop the fundamental platform, where the improvements will be available to everyone. The platform has no inherent research value apart from being a platform for novel research activities, so 3rd party development only lowers the barriers to developing more advanced wireless CM systems in the future. The Power Networks Demonstration Centre and the Wind Turbine CM group at Strathclyde have already expressed interest in using the platform. There still remains an opportunity to publicise National Grid and the Uinversity of Strathclyde involvement in this as it represents the first open source standards-based industrial WSN platform of its kind, so is truly a world leader in that respect.
- The ISA100.11a standard provides native time synchronisation giving an accurate timing reference on each sensor node. One of the key contributions of the project is the proposal that this timing information can be used to phase resolve RF PD data. Investigations into this have found that the theoretical models of sensor network timing errors suggest that clock accuracies in the region of tens of microseconds are obtainable, which equates to a phase error of a fraction of a degree. Further work has been proposed to test this under experimental conditions.
- Simulation of PD defect classification in the presence of clock errors has found that PD classifiers are generally tolerant to up to half a millisecond of clock error. This demonstrates that when classifying a PD defect in the presence of clock error, a clock error of up to a few hundred microseconds has little effect. This level of precision is theoretically possible under ISA100.11a, so it is feasible that remote RF PD sensor nodes can resolve PD activity against electrical phase using their own local clocks (and a suitable scheme for resolving phase against absolute time).
- One of the key bottlenecks of building such a sensor is deploying and maintaining diagnostics on-sensor. Diagnostic models may not be applicable to certain pieces of plant or may become obsolete over time. Through investigating 3 different statistical feature vectors which distil raw PD pulse measurements into statistical measurements, it was found that an optimised feature vector developed by Georgia Tech gives meaningful diagnostic results with a very small feature set and low processing and memory footprint - ideal for microcontroller applications. The

	COMMAS system developed by the University of Strathclyde over the past 10 years used a 101-feature vector developed by Gulski which is fairly computationally complex. Georgia tech only has 7 features and their method of calculation is trivial to implement, only requiring a few hundred bytes of memory. The most interesting result of applying Georgia Tech's work is that it obviates the need to deploy diagnostics on-sensor. With only 7 values to transmit, statistical features can be transmitted over the wireless link and diagnostics and trending can be carried out on a PC. Initial results from using this also identify it as having the potential to be used as an anomaly detector, which could potentially be used to weed out non-PD events or identify changes in PD activity over time. • Investigations into off-the-shelf devices for PD detection have been fruitful. The MAX4003 RF detector is used in mobile phones to calibrate RF transmitter power. This device was identified, amongst similar devices, as being a candidate for an off-the-shelf PD detector. A study into the performance of this device has found that it can detect PD down to at least -60dBm, nominally using 7mA at 3V. The MAX4003 chip only requires an additional 2 capacitors and a resistor so they are cheap (< $1 at volume) and simple to implement. • The most difficult part of the puzzle is digitising PD pulse data on a microcontroller so that measurements can be supplied to a feature vector calculator. While the MAX4003 supports low-power PD detection and the Georgia Tech feature vector supports low-power, on-sensor data processing, capturing PD pulses using the current generation of analog-to-digital converters is not feasible without the development of interfacing circuitry which, in its nature, will affect the measurement precision. This is still an open problem and requires further work to implement. • Strathclyde are currently looking for a replacement student to continue this work.
Collaborative partners	
R&D provider	University of Strathclyde

Project title	A Probabilistic Wind & Ice Map for the UK		
Project Engineer	Boud Boumecid		
Description of project	The Main objective is: • To provide a probabilistic UK wind/ice map to be used in the design of overhead lines using BSEN 50341/50423.		
Expenditure for financial year 12/13	Internal £5k External £33k Total £38k	Expenditure in previous (IFI) financial years	Internal £3k External £38k Total £41k
Total project costs (collaborative + external + [company])	£78k	Projected 2013/14 costs	£0k
Technological area and/or issue addressed by project	Currently UK electricity network owners have adopted BSEN50341 and BSEN50423 standards using either the 'general' approach to line design (BS8100) or the deterministic 'empirical' approach using fixed wind/ice parameters. The latter approach has been used for the design of National Grid's exiting overhead line (OHL) network. CENELEC standards allow alternative line designs based on probabilistic methods if evidence can be given of wind/ice loads. The COST727 project will provide the modelling tools necessary to develop a wind/ice map of the UK which will relate weather data to conductor ice loads. This will allow return periods of wind/ice loads to be evaluated on a geographical basis. Future UK line design can follow these new wind/ice loads which are expected to be less onerous than those predicted by BS8100, produced in 1986 mainly for the design of communication towers. Due to the tremendous developments over the last decades in global weather observations and computer capacities, the knowledge of physical and dynamical processes in the atmosphere have progressed accordingly, and indeed led to greatly improved quality and reliability in modern weather forecasts. It is therefore now possible to better describe the water cycle and the related phase transitions in clouds, as well as details in the formation of precipitation. In addition, the accuracy of forecasts of air temperature, wind speed and wind direction has improved significantly. In order to obtain such details in the lower atmosphere, it is also necessary to include adequate details of land and sea surface properties such as topography, land surface conditions, (forests, towns, lakes, farm land, snow cover, etc.), and also sea surface temperatures. By using nesting technology from global scales, it is possible to model local weather down to spatial scales relevant for span lengths of electric overhead power lines in 3-D topography. Every 6 hours the state of the atmosphere is analysed on a global scale and all parameters are stored in a 3-D gridded data base, covering the globe and throughout the atmosphere. This data base represents a synthesis of all measurements and observations from regular weather stations, radar automatic stations in remote areas of the Earth and radio soundings, in addition to data from radars and satellites. Hence, each grid point will provide comprehensive and reliable information on the state of the atmosphere to an extent which hardly any single weather station can comply with, other than for particular site specific applications. A model often used for advanced atmospheric applications is called the		

	"Weather Research and Forecasting", (WRF), model, and is a state-of-the-art meso-scale numerical weather prediction system, used both in operational forecasting and also in atmospheric research. WRF solves coupled equations for all important physical processes, such as winds, temperatures, stability, liquid water content in clouds, types and amounts of precipitation, etc., in the atmosphere based on initial fields and lateral boundary values derived from global or regional analysis data. Hence, the WRF model provides realistic input data for post processing with conventional models concerning accumulation of different types of atmospheric icing, including rime, (in-cloud), icing, wet snow and freezing rain. Due to atmospheric icing often occurs as a very local phenomenon, and icing intensity varies greatly in space, especially in complex terrain, modelling of icing requires a very high horizontal resolution. To deal with this challenge the model may apply grid spacing often in the range of 0.4 – 0.8 km, which is considered as extremely high resolution for meso-scale models The WRF-based icing model developed by Nygaard under the COST programme will be applied to the UK Overhead Line network with the aid of Svein Fikke, a consultant meteorologist who has worked on ice load predictions for Norway and Greenland for many years.

Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		12	0	12

Expected benefits of project	Currently, tower and foundation strengthening work is being carried out on many OHL schemes, depending on geographical location and the proposed conductor system. On the ZK and ZX OHL routes, an approach has been adopted by collecting local wind data form the MET office for the purpose of developing a wind map specific to parts of these routes. Savings > £10M have been achieved including a reduction of 60T strengthening steelwork, upgrading of 40 foundations was avoided and 60-70 towers avoided replacement. This cost excludes double circuit outage charges and health and safety and environmental impact.

Expected timescale of project	2 years	Duration of benefit once achieved	5 years
Probability of success	80%	Project NPV = (PV benefits – PV costs) x probability of success	£342k

Potential for achieving expected benefits	The Project has a likelihood of success high with implementation via technical expert.

Project progress [Year to End of March 2013]	**Stage 3 of the development of a probabilistic wind and ice map for the design of overhead lines in the UK is now complete.** **Stage 3 deliverables included:** • **Production of high resolution wind only, ice only, combined wet snow and rime ice maps of UK.** • **These maps to be provided at a 2km resolution for a 50 year return period with wind speeds at 10m above ground.** • **The ice loads (wet snow and rime ice) to be presented as kg/m ice loading on a geographical basis at actual land heights.** • **The output will be based on OS grid reference points or GPS locations which will include both wind and ice loads at the specified resolution of 2 or 10km boxes.** **Actual stage 3 deliverables are:** • **The final resolution obtained was 500x500m, not 2km as stated as a deliverable.** • **A further map was produced based on the successful validation of estimations of the liquid water content of snowflakes.** • **This allowed the 'stickiness' of snow flakes to overhead lines to be evaluated (wet snow sticks when the liquid water content is between 15 and 40% of the snowflake).** • **This process also allowed the densities of the accretions to be determined.** • **This was also produced as an additional map to allow for radial ice thickness to be determined from the ice loads – required for wind loads.** **A stage 4 is currently being proposed as below:** • **The scope of the project is to take the information obtained in Stage 3 of this work and use this to provide a user-friendly software programme to determine exact loadings based on a number of User Inputs to determine the exact loads applied to conductors in the 500mx500m grid. This information can further then be fed into Overhead Line Design packages.** **.**
Collaborative partners	
R&D provider	**EA Technology Ltd**

<table>
<tr><th>Project title</th><th colspan="4">GIC DGA Monitoring and Alerting</th></tr>
<tr><td>Project Engineer</td><td colspan="4">Graham Moss</td></tr>
<tr><td>Description of project</td><td colspan="4">This project will deliver the ability for National Grid to assess whether significant DC current (induced from charged particles streaming into the atmosphere from solar events) are passing through power transformers, thereby allowing instant notification of potential over-flux and failure, but also for the first time, an integrated system of on-line dissolved gas analysis (DGA) systems which will produce the evidence of any fault activity caused by the DC current within minutes of the event. All data captured will be high resolution (second by second) and be handled, viewed and automatically alarmed through the Condition Monitoring strategic asset management (SAM) platform.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td>Internal £5k
External £75k
Total £80k</td><td colspan="2">Expenditure in previous (IFI) financial years</td><td>Internal £4k
External £201k
Total £205k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£294k</td><td colspan="2">Projected 2013/14 costs</td><td>£9k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">During periods of high solar activity, millions of tonnes of highly charged particles are ejected away from the sun during solar flares. As these particles approach earth, depending on the polarity of the particles, the earth's magnetic field will either deflect them or draw them into the upper atmosphere down the lines of magnetic field.

As the particles stream through the atmosphere, then induce ground level charge of the opposite charge (much like lightning only of several orders of magnitude higher current). This induced ground current (under earth rotation) travels across the surface of countries, passing along the easiest (or most conductive) route. Unfortunately this often means overhead lines and cables. On the whole, the lines and cables are able to cope with this, but the transformers at the end of each circuit are at significant risk of over-fluxing and consequently the AC power component spills out of the core windings and flows around sections incapable of supporting it.

Overheating and damage to internal components can be disastrous, causing potentially catastrophic damage to windings. In these cases, it is not enough to simply detect the presence of the DC current, but it is absolutely necessary to have in place the ability to detect the early signatures of gas being produced from early failure modes.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>10</td><td>0</td><td>10</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">1. Direct, early detection of Geo-magnetically Induced Current (GIC) using ISL gateways to run second by second analysis via a Hall Effect current transformer (CT).
2. Direct, early detection of any fault activity in the wake of a GIC event at the transformer using on-line gas analysers, also</td></tr>
</table>

	monitored through the ISL gateway. 3. Condition Monitoring data from the substations to be monitored and alarmed automatically via SAM. 4. Ability to detect onset of catastrophic failure thereby enabling early switch out of the asset. 5. Ability to detect unusual gas activity alerting Asset Engineering of the need to keep a close eye on those assets. 6. Ability to reduce risk of to personnel working on the substation of a failure through early warning systems already in use for OESB04/2005. 7. Ability for Network Configuration changes to deal with impending loss of multiple assets.		
Expected timescale of project	5 years	Duration of benefit once achieved	5 years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£241k
Potential for achieving expected benefits	Based upon preliminary work assessing the new DC detection CTs coupled with our confidence of SAM based monitoring of on-line gas analysis systems to pick up early stages of asset failure, the chances of success are very high.		
Project progress [Year to End of March 2013]	15 Transformers have been fitted with the prototype Hall Effect CTs for monitoring GIC effects along with 15 gas analysers for follow up evidence as to whether any GIC event caused internal damage. 2013 is the solar maximum year in which solar flare activity is predicted to be most active in an 11 year cycle. Ther has been a focus on tuning this system and some new CTs are expected to be required for specific levels of GIC. Doble have been calibrating the installed R&D systems (when outages allowed). The calibration is specific to each transformer and requires the CT to be manually altered to obtain a reference 'Zero' baseline based on actual recorded data. All sites that are active continue to operate well (within the restrictions of the technology). Data connection to the server is not always 100% but that is due to the remote locations having limited cellular coverage. A commercial system based on the R&D, but utilising National Gid's new Generation-3 condition monitoring gateway, has been developed to be available for new installations identified as being 'At risk' of GIC. The Gen-3 gateway offers a major benefit of being capable of easy connection to RAMM, significant (expandable) memory and full remote access. One Transformer is still awaiting connection at Norwich Main. Outage and Risk Management Hazard Zone control have impacted heavily on access to specific units. All data from the active units is being uploaded to SAM and trend analysis is working well. All the R&D gas analysers chosen to detect serious faults are working very well.		

	To complete the objectives of the R&D, the final components are: Replace 1 signal conditioner (Failed and stopped working). Install the CT to SGT1 at Norwich Main. C3 to modify the graphical user interface on SAM to reflect the new changes to the calibration.
Collaborative partners	
R&D provider	Doble PT, Invisible Systems, C3Global

Project title	Detection and Measurement of ACSR Corrosion			
Project Engineer	Michael Hannon			
Description of project	Development of a replacement for existing Aluminum conductor steel-reinforced (ACSR) Conductor Corrosion detection equipment.			
Expenditure for financial year 11/12	Internal £10k External £125k Total £135k	Expenditure in previous (IFI) financial years	Internal £8k External £1k Total £9k	
Total project costs (collaborative + external + [company])	£164k	Projected 2013/14 costs for National Grid	£20k	
Technological area and/or issue addressed by project	Conductor life and reliability are of increasing importance as ACSR conductor reaches the end of its technical asset life. Conductor condition information is vital when making optimised asset replacement decisions. Approximately 20 years ago, the CEGB developed non destructive test equipment to measure steel core loss. The equipment developed from this project is still in use and is the only proven method of detecting loss of galvanising in ACSR conductors. The existing equipment is obsolete and increasingly difficult to operate and maintain. The analysis software runs only on legacy hardware and with unsupported DOS software only. There is no modern equivalent equipment available world-wide.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		10	-3	13
Expected benefits of project	There is a requirement to maintain and reliably operate ACSR conductor to end of asset life. Investment decisions on scope, timing and prioritisation of full refurbishment or fittings only schemes are informed through condition information. The capability to deliver an optimised overhead line (OHL) asset replacement plan relies on the ability to select suitable routes for fittings only schemes. Without ACSR corrosion test equipment, extensive in span destructive sampling would be required leading to additional longer system outages, additional site resources and thus higher costs for collecting the condition information. With a sharp increase in OHL asset replacement schemes planned, it is essential that National Grid can continue to use a non destructive test to measure steel core loss and ensure condition information can be accurately and efficiently collected. Without this equipment it is expected that the costs for collecting the condition information will increase from £1500 to £4500 for each section of a route where condition information is collected. This could equate to an additional cost of £800k for the tests which are required.			
Expected timescale of project	2 year	Duration of benefit once achieved	5 year	

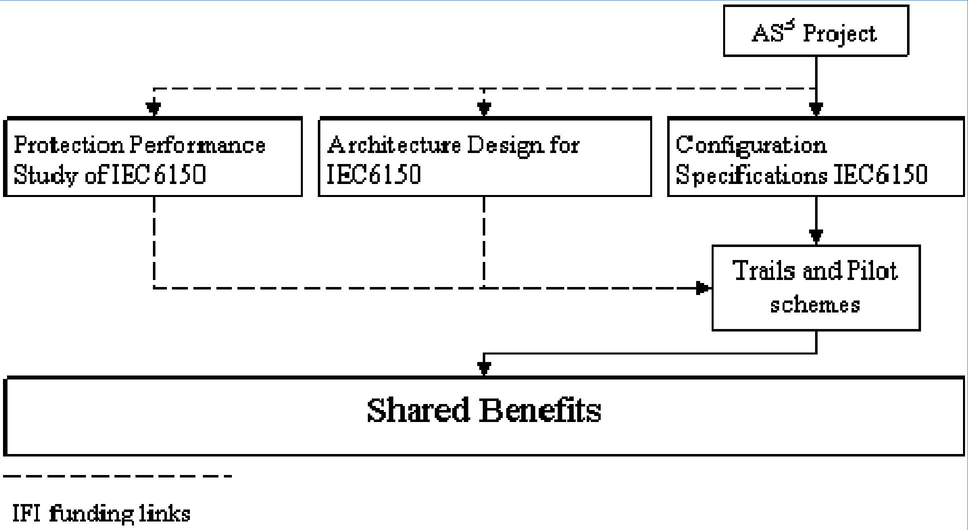
Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£232**
Potential for achieving expected benefits	**Very High. The principles of the technology are already proven. Hydro Quebec have an extensive R&D capability, driven by the same needs as National Grid and are fully committed to develop a reliable long term replacement using modern hardware and software.**		
Project progress [Year to End of March 2013]	**National Grid and Hydro Quebec are working in collaboration to establish an updated version of the ACSR condition assessment probe. During 2011/12 National Grid and Hydro Quebec joined forces to understand the theory behind the technology and began work on a working prototype.** **Initial testing of probe configurations has proved successful and a trial of a working prototype was scheduled for September 2012.** **The probe has continued to develop. In September 2012 a prototype version was demonstrated to show that the sensor could identify areas of concern on conductors. Software and output visuals were also demonstrated.** **The probe is presently going through its next stage of development which is to provide the ability to work on live conductors.** **As part of the acceptance testing program, National Grid are planning to undertake an inspection on a conductor in need of forensic testing. The activity has been planned for October 2013.** **On successful conclusion, National Grid anticipate receiving an industrialised unit in March 2014.** **During the development of the probe the technology has provided results to date that indicate that, with further research investment, the probe has the potential to provide additional forensic information beyond its designed intention. This is an exciting development which will provide further asset condition data allowing National Grid to operate, in confidence, a safer and more reliable system and to invest in major infrastructure at the optimum time.**		
Collaborative partners			
R&D provider	**Hydro Quebec – IREQ**		

Project title	HVDC EngD - Richard Poole		
Project Engineer	Paul Coventry / David Fidler		
Description of project	Transmission system power flows are changing due to different generation locations, traditional power flows north to south changing, saturation of parts of the transmission system leading to reinforcements and strategic Investment. The project combined three work packages: Future Generation connection (HVDC) ■ Analysing the possibility of connecting future generation types such as (Nuclear, Wind etc..) to the Grid via HVDC ■ VSC Convertor technology will be analysed. ■ System dynamics will be studied. ■ Fault analysis is also covered. ■ Reactive power flow and control. LCC and VSC convertors ■ Comparison of the above two technologies. ■ Available power transfer capacity. ■ Sub synchronous resonance. ■ Sub synchronous torsional interaction. ■ System Dynamics. ■ Fault analysis. FACTS and HVDC technology ■ Interaction between FACTS and HVDC. ■ System Dynamics. ■ Stability Considerations. ■ Fault analysis. ■ Reactive power considerations The project will be delivered by an Engineering Doctorate (EngD) in an area of the company which will become increasingly important over the upcoming years.		
Expenditure for financial year	Internal £4k External £5k Total £8k	Expenditure in previous (IFI) financial years	Internal £3k External £10k Total £13k
Total project costs (collaborative + external +	£30k	Projected 2013/14 costs for National Grid	£19k

[company])				
Technological area and/or issue addressed by project	HVDC as above			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		5	-2	7
Expected benefits of project	The benefits will be gained through the improvement in knowledge of a National Grid employee and working on an area identified as needing more knowledge within the business. The knowledge and learning by Richard will be directly translated back into the company. Benefits will accrue through: ■ Research relevant for future industry requirements. ■ Research on HVDC technologies and interaction with the existing power system. ■ Potential for Technical Procedures, Technical Specifications and Policies to be produced for use and guidance. ■ Research carried out has the potential to provide expert guidance for future customers associated with requests for HVDC Grid connections.			
Expected timescale of project	4 years	Duration of benefit once achieved	Years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£17k	
Potential for achieving expected benefits	There is a high likelihood that the student will complete the EngD, therefore the knowledge learning and understanding will be directly transferred into the business and more widely the industry through both industrial and academic dissemination.			
Project progress [Year to End of March 2013]	Started to carry out modelling on Power World Simulator versions 15 and 16 to gain an appreciation and high level understanding of how HVDC interacts with the AC network. Areas such as fault analysis, outage scenarios, reactive power issues have been investigated as part of the original Literature review expected during the first 12 months of the EngD programme. The knowledge gained from this initial phase of the literature review will now be carried forward to the next phase to be applied to PSCAD power system analysis software to start the first official project of the EngD programme looking at HVDC and AC system interaction (Faults/outages etc.). A visit to Torness Nuclear Power Station, as part of an IET member visit provided knowledge and practical insight that will be applied to the project during the initial write up phase. A visit to Hinckley Point Power Station			

	has been arranged for Tuesday 18th June 2013 to see the existing Hinckley point B reactor and the future C reactor respectively. PSCAD HVDC power systems analysis software has now been acquired. All three individual HVDC projects that make up the EngD are ready to be started as soon as the software has been installed on the company laptop. On job HVDC experience and learning is progressing well and is being continuously applied to the EngD on a day to day basis through work based application.
Collaborative partners	**N/A**
R&D provider	**University of Hertfordshire**

Project title	Protection Performance Study for IEC61850 Process Bus Architecture of Substation Secondary Systems (AS^3)				
Project Engineer	John Fitch				
Description of project	Maximising economic and effective utilisation of the transmission assets and network is the key objective. The deployment of the technology advocated in this project will allow ongoing substation secondary equipment retrofitting (refurbishment) projects to proceed whilst limiting the duration and frequency of circuit outages, required to facilitate the work. Once the new technology is installed, secondary equipment renewals occurring mid-life in the primary plant lifecycle can be undertaken in a safer, quicker and easier way with much reduced outages of primary systems. At any time, secondary system upgrades and modifications can be undertaken without a primary circuit outage. This will also significantly reduce the outage period required for substation extensions. In order to pursue this strategy, sufficient confidence must be demonstrated in the philosophy and the new technology, hence the need for the IFI research. The work is thus strategic, aligned to the AS^3 project and is designed to understand the impact of the emerging technology of process bus architecture on the performance of protection and control equipments.				
Expenditure for financial year	Internal £6k External £13k Total £19k	Expenditure in previous (IFI) financial years	Internal £11k External £174k Total £185k		
Total project costs (collaborative + external + [company])	£330k	Projected 2013/14 costs for National Grid	£0k		
Technological area and/or issue addressed by project	The key objective of this project is to investigate, quantify and optimise the level of security, dependability and operating speed in secondary schemes using IEC 61850. As a precursor to wide deployment of the philosophy in AS^3 project, it must be ensured that the performance of the protection and control scheme meets or exceeds that of its hardwired predecessors.				
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score	
		8	2	6	
Expected benefits of project	This project is linked to the AS^3 project contributing to increased likelihood of success of the project and therefore has shared benefits with AS^3.				



The separate business benefits of the project are:

- **Understanding the impact of emerging technologies on the future protection and control systems to support National Grid's decision-making.**
- **Taking full advantage of the emerging technologies while identifying and minimising potential risks.**
- **Providing a proper basis for the development of future protection systems based on the experience of the protection schemes being studied.**
- **Less site commissioning required for the new protection systems. Most of the tests can be carried out in factory by software simulation using the IEC61850 process bus.**
- **Much reduced outage required for the future replacement of the new protection and control equipments.**
- **Maximising economic and effective utilisation of the transmission asset and network.**
- **Safety, health and the environment is improved by reducing the need for cross-site secondary circuit cabling, mitigating the associated risks.**

Expected timescale of project	**4 years**	**Duration of benefit once achieved**	**5 years**
Probability of success	**40%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**-£219k**
Potential for achieving expected benefits	**Following the literature survey and evaluation of possible topologies for bay process bus and station bus architectures, it became apparent that current 100Mb Ethernet switches and Merging Unit (MU) limit the number of MU on a process bus to a maximum number of 8 units. This limitation may restrict the application of the IEC61850 architecture depending on the size of a substation. It is anticipated that 1Gb switches and MU will be developed by manufacturers, the full benefits of the project can then be achieved when the 1 Gb units are available.**		

	The test on the feeder bay using different manufacturer's merging units revealed some compatibility issues. The test results obtained so far indicate that with current prototype of merging units, the IEC61850 system has some reliability issues, however when manufacturers fully develop their products say in 2 ~ 3 years, the reliability will be improved and the process bus of sampled values can then be implemented.
Project progress [Year to End of March 2012]	The project started in Jan 09, during the first three months, literature survey of the IEC61850 process bus architecture and its impacts on protection performance have been completed. The trial topologies to interconnect the protection relays have been established. The protection panels were built and delivered to University of Manchester for testing. Relay firmware has been updated. Initial tests on relays using simulation software of IEC61850 data have been completed. Test bench using Omicron test sets were set up and relays were configured for the stage 1 testing. Full stage 1 tests have been completed and have highlighted complications with the merging units. Both the feeder protection and the transformer protection schemes have been tested and reports submitted. These have confirmed the correct operation of these units. Simulation studies have examined the characteristics of the main variants for the process bus topologies and these have been supported by practical implementations. Based on these and practical considerations of the operation objectives of using the IEC61850 system, Star configurations have been chosen for the process buses. Having developed simulation models of the process bus structures, initial studies have been undertaken on the possible failure modes of the IEC 61850 based communications. It has been generally confirmed that the current 100MB communications will handle the communications requirements of the scheme being examined. Further analysis is in progress, using probabilistic studies to better define the 'safety margins' and predict where data congestions may occur and their consequences. Tests on the feeder protection units and the transformer protection units using the real time digital simulator (RTDS) test system demonstrated that the IEC61850 protections performance was comparable to the conventional protections. Tests to determine the response to communications system collapse and overload demonstrated that the IEC61850 relays performed as required albeit slower under any of the test conditions and during communications overload. These results have dispersed any concerns over communications system failures. The results have now been documented and the final reports generated. Presentations have been given by the researchers and their supervisors to the main stakeholders in the project and the two theses arising from the two PhD students have been written and issued. A number of high quality papers have already been presented at various events and in a number of journals reporting on this project and informing the wider market on some of the application and performance issues arising from this new technology solution. The information from this project is now informing the future application of IEC 61850 Process Bus through development of draft Policies and Specifications and is illustrated by the two recent AS^3 pilot installations installed by NR Electric and ABB with Process Bus technology, on the National Grid Transmission system.

Collaborative partners	**Areva, Scottish Power, Scottish & Southern Energy**
R&D provider	**University of Manchester, University of Bath**

<table>
<tr><th>Project title</th><th colspan="4">Design of a smart tool for detecting hidden errors in protection setting files</th></tr>
<tr><td>Project Engineer</td><td colspan="4">Tahasin Rahman</td></tr>
<tr><td>Description of project</td><td colspan="4">This project will deliver an intelligent tool (a computer software application or expert system) which can open a setting file and interrogate the protection functions and settings in the file. Knowledge-based rules and/or cases (and possibly other knowledge-representation methods) will be extracted and these will be deployed within an intelligent system in order to ascertain that no settings are erroneous. This includes checks that relay settings are correct and that no features are inadvertently enabled or disabled.

The knowledge used to assess the validity of settings will be derived from National Grid protection application/settings policy documents and also (possibly) from structured knowledge elicitation interviews conducted with expert personnel from the company.

A simple power system model will be used by the tool to test the settings to validate that they are correct and to provide a further means of checking for hidden errors by applying various in-zone and out-zone faults on the power system model.</td></tr>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £6k
External £47k
Total £53k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £6k
External £33k
Total 39k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£91k</td><td>Projected 2013/14 costs for National Grid</td><td>£41k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">Relying solely on people and procedures to assess the validity of protection relay setting files has not always been successful and occasionally hidden errors were not detected until after a relay mal-operated. In addition, a mal-operation related to an inappropriate setting may only become apparent when the power system is operating in a stressed or abnormal state and consequently might cause a local black-out or trigger a regional collapse.

Setting errors, or hidden problems in the setting files used in protection relays, have resulted in mal-operations. This project will investigate a method based on an expert system that will detect hidden errors in a setting file.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>8</td><td>1</td><td>7</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Recent increases in the complexity of numeric relays, and the associated rise in the number of settings applied to a relay, have increased the risk of an incorrect setting failing to be detected. The consequence could be a multi-circuit trip, or in a worst scenario, a blackout. The proposed expert system will detect the setting error and prevent it being applied to a relay before commissioning. Additionally, the existing settings previously approved and commissioned can be verified and corrected if</td></tr>
</table>

	necessary. Therefore, the main business benefits are improved transmission system reliability, minimisation of protection mal-operations and the maintenance of National Grid's reputation for quality.		
Expected timescale of project	3 years	Duration of benefit once achieved	5 years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£225k
Potential for achieving expected benefits	The track record of the University of Strathclyde in collaborating with industry for the research and development of intelligent systems, and in particular, the analyses of protection system design and performance, is excellent. They have carried out several research council and industry-funded projects, including: EPSRC SUPERGEN5 Asset Management and Performance of Energy Systems (AMPerES), Highly Distributed Energy Future (HiDEF), Highly Distributed Power Systems (HDPS) and FlexNet. The prior experience and capabilities of the academic team at the University of Strathclyde, the established relationship with National Grid and the high quality of the identified PhD candidate all contribute to an increase in the likelihood of success of the proposed project.		
Project progress [Year to End of May 2013]	The project has been progressing well in accordance with its proposed schedule. A prototype of the smart tool has been developed. It supports text file setting information parsing from six frequently used relay types. Rules have been extracted from the setting policies to verify two-ended 400 kV and 275kV circuit with plain/blocked distance protection, and to verify unit protection on 400 kV, 275 kV and 132 kV transmission lines. The prototype is also able to detect if any functions are inadvertently enabled or disabled. The first version of the prototype is currently under refinement and testing. In the meantime, more parsers and rules are being developed in order to support more relay types and protection schemes. Based on National Grid's existing protection setting process, two modified setting processes are proposed which incorporate the smart tool at some stage to verify the settings. One approach is to use the tool to parse the information from plain text files (as the current prototype does) and carry out the existing setting verification, and the other approach is to parse the information from files exported by vendor-specific tools (e.g. Alstom MiCOM S1 Studio). Both suggested processes will be presented during the next project review meeting between Strathclyde and National Grid in May 2013. The advantages and disadvantages of each approach will be discussed in order to achieve the optimal decision regarding the integration of the developed tool into the National Grid setting process. With regard to academic output from the project, one conference paper (UPEC 2011) has been published to date; another conference paper has been accepted by the 2013 IEEE PES General Meeting and will be presented in July 2013; a synopsis has been submitted to the 2014 CIGRE Paris Session which is currently at the national review stage; additionally, a journal paper is also under preparation. National Grid will be co-authored and acknowledged in all these publications. In summary, the project is progressing according to the original schedule and is on target to be completed within the assumed		

	timescales.
Collaborative partners	**N/A**
R&D provider	**University of Strathclyde**

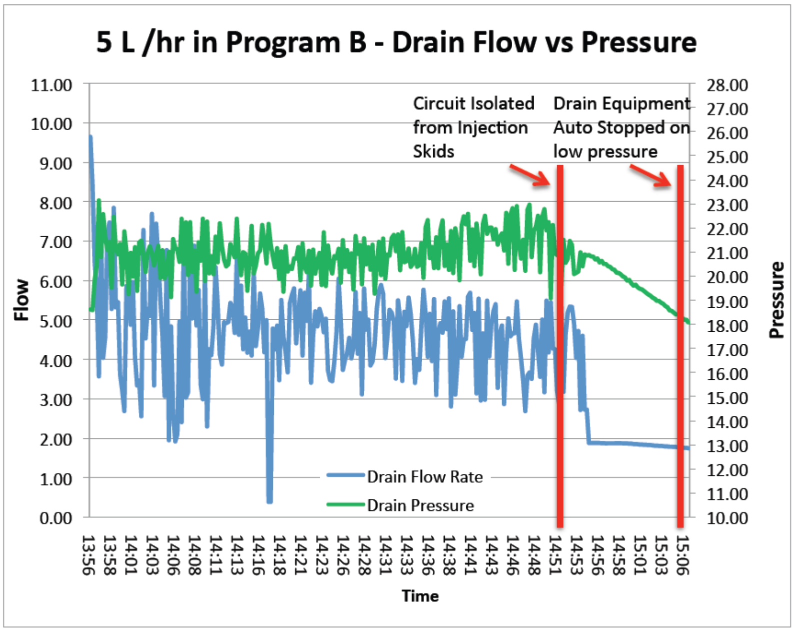
Project title	Further Development of PFT in Service Cable Oil Leak Location Technique			
Project Engineer	Mike Fairhurst			
Description of project	Goal – To provide National Grid with a leak free oil filled cable system and to inject preventatively all transmission cables with PFT tagged fluid. PFT in service leak location technique, employing Peroflurocarbon tracer (PFT) to "tag" the cable oil. has now been adopted as the main tool in oil leak location which has seen a significant step change in the way in which National Grid responds to oil leaks with improvement to the speed and accuracy of leak location combined with the sensitivity to locate low rate oil leaks, that in the past have been difficult if not impossible to locate with previous techniques, as a result major reduction in outage times to effect repairs (65%) are now being achieved. Phase 1 & 2 of the original project proved the technique could be used on both 132 & 275kV cables without any detrimental effect to the long term performance of the cable and accessories. Phase 3 of the project is further develop the technique for use at 400kV and to also reduce outage time by introducing the PFT in to the cable while the cable remains in service, without the need for an outage.			
Expenditure for financial year	Internal £4k External £15k Total £19k	Expenditure in previous (IFI) financial years	Internal £25k External £204k Total £230k	
Total project costs (collaborative + external + [company])	£244k	Projected 2013/14 costs for National Grid	£0k	
Technological area and/or issue addressed by project	High Voltage oil filled cables – Non intrusive cable oil leak detection with the cable in service.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		14	0	14
Expected benefits of project	Reduction in costs and resources associated with cable oil leak location with potential to give an accuracy of within 2 metres on all cable voltage ranges. In 2003/04, 9 cable oil leaks required freezes for leak location, the cost of this work varied between £360k and £720k per leak location. Historically on average, National Grid spent £500k per year on cable oil freezes. Assuming PFT location reduces the requirement to freeze by 50%, this would realise a saving of £250k per year or £1.25 million over a 5 year period. Following the completion of Stages 1 & 2 a three year contract was let to tag and locate leaks on 20 275 kV cables; contact value £2.3 million or £776k per year. To date 124 cable sections have been tagged, 42 leaks have been located and repaired, without the need to excavate and freeze for location, thus reducing repair costs by some £2 million over the last 2 years since contracts were placed. In addition outage and repair times have reduced by 66% this			

	directly affects the oil loss with regard to moderate and low leaks as the volumes being lost has seen a significant reduction when compared with previous years. Phase 3 of the project will enable National Grid to extent the benefits on to the 400kV network and in addition improve the flexibility of the tagging process across voltage ranges by enabling the procedure to be carried out without the need for an outage. In summary, potential benefits are : • Improved response times for leak location hence overall repair time • Reduced oil loss resulting from improved response time • Reduced outage times and hence improved circuit availability. Improved response to cable oil leaks is an integral part of driving forward improvements in environmental performance and cable circuit availability and is consistent with National Grid's philosophy in promoting the use and development best practice.		
Expected timescale of project	**2 years**	**Duration of benefit once achieved**	**5 years**
Probability of success	**60 %**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£318k**
Potential for achieving expected benefits	**Benefits are currently being realised from previous Phase 1 & 2 projects; reduction in OPEX costs, reduced circuit outage time (two thirds) reduction in civil works on roads therefore benefiting road users and local residents. It therefore expected that the benefits will be applicable to National Grid's 400kV cable network.**		
Project progress [Year to End of March 2013]	**The equipment has been designed and undergone lab testing in the US with a field trial conducted in the UK. The equipment performed as expected. No major modifications required. We have met the requirements of the project, and demonstrated the tag is successful and can be added to oil filled cables, with the cable in service. One of the major targets for this project was to be available for use during the Olympics. This target was met.** **Next steps, in a different project, would be to identify a need case (operationally) for a tag specific to National Grid. These discussions are currently being held within National Grid.** **This oil leak detection system has now been adopted by the distribution network operators (DNOs) – notably UKPN - which has led us to require development of a protocol with UKPN & PFT Tech, which can identify the correct company's cables, rather than just a positive/negative result. This should be addressed at the Cable Accessory Panel within the ENA.** **Prior to shipping the "Live Injection" equipment for field trials in the UK, it was shipped within the US to ensure it shipped without damage. Several vulnerable areas where damage occurred were discovered and corrected.** **Initial visual inspection of the Injection equipment indicated that the equipment had shipped safely to the UK. The entire electrical system was tested and no**		

	issues were discovered. During testing, as the systems ran, relatively large variations in the flow rate were observed. Rather than zeroing in on the user entered flow rate, the flow rate was observed to oscillate between two values. It was determined that the source of the issue was the difference in the viscosity between the dielectric fluid used in the US and that used in the UK. Alterations were made to the drain and injection equipment valves which allowed the flow rate to zero in on a target flow rate. Further examinations will take place once back in the US. Throughout all of the initial testing, all of the messaging, communications and data logging abilities were tested and successful.
	Below is a picture of the Injection Equipment in Rowdown Substation, The Injection Equipment, which includes all electrical and hydraulic components, can be seen, in addition to the tank of PFT concentrate. 

Below is a picture of the drain equipment. The hydraulic components can be seen positioned on the drum, while the electrical components are resting below.

The results of the field test designed to simulate an actual Live Injection are shown in the graph below.



As can be seen from the graph, the system maintained the pressure (on average) above the Falling Alarm Point (21 psi), until we manipulated the process for testing purposes.

	Overall, PFT tech was very impressed with the operation of the "Live Injection" equipment on the field. Many man-hours were invested to ensure that the system was designed and operating properly, however, the true test was connecting the equipment to an actual circuit. Through all tests the equipment demonstrated its ability to establish and maintain a flow through a circuit, while injecting the proper quantity of PFT concentrate.
Collaborative partners	**PFT Technology**
R&D provider	**Pirelli & PFT Technology inc**

Project title	Optimising the operation of an integrated DC link within an AC system			
Project Engineer	Alex Carter			
Description of project	Determination of how the system should be operated with the introduction of offshore HVDC lines to maximise the exploitation of renewable energy resources, especially wind and the types and amounts of reserve that are likely to be required.			
Expenditure for financial year	Internal £4k External £11k Total £16k	Expenditure in previous (IFI) financial years	Internal £7k External £60k Total £67k	
Total project costs (collaborative + external + [company])	£105k	Projected 2013/14 costs for National Grid	£0k	
Technological area and/or issue addressed by project	National Grid has a good history of operating the AC network and also utilizing a DC link as an interconnector. However National Grid has no experience in operating an integrated HVDC link in conjunction with the AC system. The first intra-network HVDC line is planned to be operational from 2013 to accommodate the significant increase in wind generation being installed in Scotland. It will be the responsibility of the System Operator to determine the optimum power flow on this link by balancing the risks and flows between the parallel AC and DC networks.			
Type(s) of innovation involved	Radical	Project Benefits Rating	Project Residual Risk	Overall Project Score
		10	0	10
Expected benefits of project	This project will contribute to ensuring that the correct balance between security and efficiency is maintained by advising on the best strategies to approach setting the flow between the parallel AC and DC networks. This will need to factor in transmission losses and stability for a range of different operating conditions and understand the consequences that this will have. The main benefits to the system will be a study enabling the understanding of: • The risks associated with different levels of power dispatched pre-fault on the HVDC link that is being operated in parallel with the AC. • Advice on suitable levels of dispatch on a parallel HVDC link. The dimensions of risk are expected to include risk of overloads on the AC system and risk of rotor angle instability on the exporting side of a boundary following a fault outage. The scope for different levels of inter-trip to manage the above risks will also be explored alongside the need that remains for pre-fault constraint of generation under different circumstances. Finally, through liaison with CIGRE JWG C4.B4.C1.604 (“Embedded HVDC”), knowledge will be sought on emerging international practice in respect of the above and on fault rates on the HVDC side.			

	This study will be critical into maximising the exploitation of the renewable energy resources in the North of Britain as well as ensuring minimisation of balancing services costs associated with operating the system. Analysis was carried out in July 2010 to assess the Interim Connect and Manage over the period 2010/11 to 2014/15 and shows that the boundary between England and Scotland will remain congested and constraint costs are likely to be approximately £75k/MW/year. The cost of the project is therefore equivalent to the constraint cost of reducing pre-fault flows by 2MW for one year.		
Expected timescale of project	4 year	Duration of benefit once achieved	5 years
Probability of success	50%	Project NPV = (PV benefits – PV costs) x probability of success	£187k
Potential for achieving expected benefits	An encrypted version of the GB network model is now available and the University of Strathclyde has the correct level of knowledge so this project has a high likelihood of success.		
Project progress [Year to End of March 2012]	A PhD student was been appointed from the University of Strathclyde's partnership scheme with North China Electric University. Co-funding has been obtained from the Scottish Energy Technology Partnership (ETP). Objectives in the first year concerned attendance of Master's level classes to improve background knowledge and conduct of analyses of power system steady state security. Some analysis has been carried out to determine the optimum flow on the HVDC circuit and has indicated that it should be maximised over the flow on the AC network. It is anticipated that transmission loss optimisation may be required at lower cross border flows. However, some issues have been encountered with the suitability and progress of the student and they were unable to progress toward a PhD, transferring to MPhil but withdrawing from the course due to medical reasons in March 2012. To continue the progress of the work, the University of Strathclyde provided two other PhD students to complete preliminary studies using a simplified GB model. It has been decided to close this project as there is limited opportunity to find another PhD student to complete the work. Another project, 'Smart Transmission System Operation', funded through EPSRC's iCASE scheme started in October 2012 in a similar area of work. The support from the 'Operation of the future GB transmission system' project are being transferred to this iCASE project, along with the key objectives from this project. The work that has been completed will be captured in a report being produced by University of Strathclyde due in March 2013.		
Collaborative partners	STP		
R&D provider	University of Strathclyde		

Project title	Feasibility Study for Sustainable Substation Design		
Project Engineer	Paul de Jong		
Description of project	To develop a considered, workable and innovative, sustainable design for a substation new-build project in line with Transmission objectives and National Grid's corporate vision to lead the development of a more sustainable energy network using Finsbury Park Substation as an initial case study. This objective will be achieved by: - identifying options for a more sustainable design of substation with particular emphasis on low-carbon technology. - considering the whole-life cost of such options from a financial and carbon perspective. - working with designers of a substation new-build project to ensure they are practicable and will realise a benefit to the company and the local communities. The potential for retrofitting options and risks of a sustainable design will be considered.		
Expenditure for financial year 11/12	Internal £5k External £130k Total £135k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£300k	Projected 2013/14 costs	£157k
Technological area and/or issue addressed by project	National Grid is "committed to be an innovative leader in energy management and to safeguarding our global environment for future generations". Supporting this vision, our Corporate Responsibility Report states "we will only retain our right to operate by working to the highest standards, by trusting our employees to do the right thing and by running our company responsibly and sustainably". A goal of the new regulatory regime (RIIO) is to develop a reliable and sustainable energy network that gives consumers now and in the future value for money. It also aims to promote innovation that will be needed to deliver agreed outputs such as safety, reliability and a reduced environmental impact. This compelling background provides the empowerment for employees within the company to seek new ways of working that will deliver a more sustainable approach to more traditional methodologies and technologies. Substation design has seen many changes since the transmission system was first built. This has included improvements in the way environmental impacts are managed, such as reducing oil and SF_6 leaks. However, the design has never embraced sustainability by looking at the whole life cost of the asset and its relation to environmental impact. Two new substations are being built at Kensal Green and Finsbury Park to connect 400kV underground cables that will be installed in new tunnels, currently under construction in the London area. The London Power Tunnels (LPT) project is a highly visible, flagship project for National Grid that attracts much Government and media interest. It is imperative that		

National Grid should live the vision and work in a sustainable manner. The project has itself produced a "Statement of Intent" that pledges to become the industry leader in environmental sustainability. With this in mind, the LPT project provides an excellent opportunity to develop an alternative approach in the search for a more sustainable design of substation.

The new substation to be built at Finsbury Park is yet to receive planning permission. Design options are being considered with particular emphasis on visual amenity due to its high visibility in an already congested area. Sustainable options for the new build may help to progress its planning application. Any sustainable design options should therefore be prioritised at this location.

Sustainable options for building a new substation may include the consideration of:

- **energy recovery from transformers to provide the local community with a low-grade heat source (NB the local school near to Finsbury Park substation would be a potential benefactor).**
- **solar-powered energy generation to provide electricity to the substation.**
- **ground-source heat pumps to provide energy for the substation.**
- **green/brown roofs on substation buildings.**
- **sustainable urban drainage systems (SUDs) and/or sustainable wastewater management systems (eg reed beds).**
- **low-carbon alternatives to more traditional raw materials (eg low-carbon cement, recycled aggregates/metals).**
- **reduced energy consumption for operational mechanical and electrical design.**

This proposal seeks investment for the consideration of such options on the design of Finsbury Park substation. By employing a University Masters undergraduate to work with a National Grid employee, seconded to LPT for a period of six months, these options (and others) could be fully explored using current technology and business contacts within and external to the company. This work would involve a full and thorough calculation of the whole life cost of any sustainable design option, with particular emphasis on the carbon cost/saving. The calculation will include the embodied cost of carbon for the asset itself as well as the future running costs and associated carbon impacts during the operational phase. Working as part of the LPT project team will provide exposure to the design team within the Northern Electricity Alliance to ensure any sustainable design options are practicable and workable within the boundaries of existing procedures and contractual relationships.

The work may involve design change considerations for the primary assets within the substation, particularly in relation to heat exchange. Any previous work that has been carried out on energy capture must also be taken into consideration when calculating the whole life value of any design change

	assumptions. The risks of adopting sustainable options over current known methods will also be considered as part of this work. All carbon calculations will be consistent with the work currently in progress within Construction to provide a consistent approach.			
Type(s) of innovation involved	Radical	Project Benefits Rating	Project Residual Risk	Overall Project Score
		18	-3	21
Expected benefits of project	This proposal has many benefits at all levels that will help to: - meet the LPT objective in becoming an industry leader in environmental sustainability. - show progress in the five steps identified within UK Construction's programme towards more "sustainable construction". - meet the RIIO challenge to operate in a more sustainable manner using more innovative ways of working. - demonstrate National Grid's commitment to providing a more sustainable future. As well as enhancing the company's reputation, the proposal will identify real benefits to the environment and show how innovation can help to deliver a low-carbon economy. Investing time upfront in the design of the project will help to make sustainable options more viable. These benefits can be replicated across future substation projects and may be appropriate for the reinforcement of existing substation assets. The cost of carbon will become an important consideration in future investment decisions; directorates in the UK already have carbon budgets for Scopes 1 and 2 emissions. This project will help to show how sustainable options can be costed in the future to provide a more holistic appreciation of their benefit. Using the company's current cost of carbon (£52/tonne), an investment of £100k in this proposal is therefore justified from a carbon perspective if it saves over 1,923 tonnes CO_2(e). Although difficult to quantify the carbon saving associated with this proposal, experience gained from other, recent construction projects help to show this estimate is easily achievable (eg 5,000 tonnes CO_2 (e) were saved on the Harefield-Southall Gas Pipeline Project by replacing the cementitious tunnel grout with recycled glass). This work may result in changes to technical specifications which could provide the consistency in approach that is needed to progress the company's vision for a more sustainable approach.			

Expected timescale of project	**3**	**Duration of benefit once achieved**	**8**
Probability of success	**90**	**Project NPV = (PV benefits – PV costs) x probability of success**	**350798**
Potential for achieving expected benefits	**This project will achieve its aims as there will be opportunities for identifying and developing a more sustainable design for a substation. Where there is not a viable option for a sustainable alternative to traditional ways of working, the project will still be an important source of information for other projects.** **Clarity surrounding our commercial and regulatory framework will need to be obtained in relation to the potential generation of power and onward distribution to a third party.**		
Project progress **[Year to End of March 2013]**	**Endorsement received internally.** **An expression of interest was presented to the transformer manufactures to gauge interest. This was followed up by a round of question and answer sessions with each manufacture in turn to reinforce their understanding of the National Grid requirements. 4 positive responses received** **Contract finalised with ARUP to provide the required technical expertise to develop a functional specification for the alternative cooling system. This will make up the main technical package of information provided to the transformer manufacturers to tender against.** **Draft alternative cooling specification has been produced which has been subject to a number of internal technical review sessions to finalise the specification to the satisfaction standard as dictated by the National Grid stakeholders.** **Heat reclaim feasibility assessment undertaken to help steer the planning decision making process.**		
Collaborative partners			
R&D provider	**Arup**		

Project title	Rating Impact of Non-isothermal Ground Surface (RINGS)				
Project Engineer	David Payne				
Description of project	This project is proposed to deliver • An understanding of how the ratings of shallow buried cables and cables in surface troughs are affected by non-isothermal boundary temperatures; and • Recommendations for temperature conditions to be used in modelling of shallow buried cables and cables in surface troughs.				
Expenditure for financial year 11/12	Internal £6k External £79k Total £85k		Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k	
Total project costs (collaborative + external + [company])	£101k		Projected 2013/14 costs	£16k	
Technological area and/or issue addressed by project	The IEC 60287 standard describes algorithms for use with various cable laying conditions including shallow buried cables. The standard assumes ground surface temperatures to be isothermal. The FEAR R&D project undertaken by the University of Southampton confirmed that the use of isothermal surface temperatures was valid for cables buried at more than 1 metre depth but for shallow buried cables, including those in surface troughs, this assumption was shown to be optimistic, leading to possible overrating of such cables. Conversely cables may be underrated to mitigate for the unknown affect of non-isothermal temperatures. Recent cable installations have also employed low Thermal Resistivity backfills enabling a higher heat transfer rate from the cable to ground surface, potentially increasing the ground surface temperature. This leads to uncertainty in the actual cable rating available in such situations. It is proposed that monitoring equipment is installed at a site where this situation occurs with the aim of collecting temperature and air flow data over a one year period to cover all seasons and a wide range of loading. The site most suitable for this would be at the Woodhead tunnel where new trough systems have been installed between the sealing ends and the tunnel. This data would then be used by the University of Southampton to assess how surface temperature is affected leading to a recommendation of temperature range to be used in cable modelling.				
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score	
		12	-5	17	
Expected benefits of project	An understanding of how the ratings of shallow buried cables are affected by non-isothermal boundary temperatures will lead to accurate assessment of cable capability. In some cases this could lead to positive responses to cable rating enhancement requests. In the case of the Woodhead tunnel cables, when combined with low thermal resistivity backfill, this is expected to enable a substantially higher rating to be applied than at present. This would remove or defer the need for the				

	installation of a second core per phase of cable at Woodhead following the commissioning of new generation in 2017, thus potentially saving £15m of asset costs.		
Expected timescale of project	3 years	Duration of benefit once achieved	ongoing
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	5401108
Potential for achieving expected benefits	The likelihood of success of this proposal is high as it seeks to build on a successful record of work relating to modelling of high voltage cable systems at the University of Southampton. • The Tony Davies High Voltage Laboratory has over 50 years of experience of using both numerical modelling and experimental work to improve cable rating calculations. • Previous National Grid funded work in the area of cable system thermal modelling has identified situations which can not be analysed using conventional (International Standard) methods and provided bespoke solutions. • Staff at the University of Southampton have extensive experience of providing cable rating support to National Grid, particularly in the areas of numerical modelling and the provision of independent verification. In addition DOBLE have wide experience of installing and maintaining monitoring systems for National Grid and C3 GLOBAL currently provide visualisation techniques for the strategic asset management (SAM) project.		
Project progress [Year to End of March 2013]	The installation of data loggers at Woodhead was delayed until November 2012 due to issues with the logging equipment. This has now been resolved and data has been rolling into SAM since January 2013. The University of Southampton have been given access to SAM so that they can download data for analysis. This will not happen in earnest until later in 2013 so that several seasons can be captured and analysed.		
Collaborative partners			
R&D provider	DOBLE/C3/ University of Southampton		

Project Title	SF_6 Capture and Leakage Repair Technology			
Project Engineer	Simon Atkin			
Description of project	The immediate challenge is for a team from across National Grid and external suppliers to review the current leak repair methodology and implement changes to attempt to ensure leak repairs are 100% efficient. Previous experience has identified that this has not always achievable due to a number of influencing factors. Where a leak repair, going forward, is not successful a means of capturing the fugitive emissions is required. A methodology has been trialled around a leaking SF_6 gas insulated switchgear flange to prove its effectiveness during the latter part of 2012. This method utilised diverting the fugitive emission through an adsorbent material (activated carbon) which once saturated would allow the gas to reclaimed by further processing. Although this trial was successful its future sustainability is questionable therefore design changes have been made which enable the gas to be collected and pumped into a storage vessel. Both designs are based around, ideally, not needing an outage to install it, but if an outage is required because the leak infringes safety distances, it should be able to be installed within 2 days to enable installation within a weekend outage. The bottle reclamation principle is being carried forward and a prototype system is currently being designed. In addition work is being conducted with the University of Liverpool to analyse the carbon captured SF_6 to assess its suitability for re-use after reprocessing.			
Expenditure for financial year	Internal £15k External £50k Total £65k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k	
Total project costs (collaborative + external + [company])	£107k	Projected 2013/14 costs for National Grid	£40K	
Technological area and/or issue addressed by project	National Grid SF_6 loses are in the region of 12,000kg per annum from Air Insulated and Gas Insulated Switchgear (AIS and GIS). Given that SF_6 has a global warming potential 24,000 times worse than CO_2 this results in ~ 306k tonnes CO_2eq per annum or circa 30% of National Grid's UK carbon emissions. The majority of these losses come from a few of our largest leakers, often where it is difficult to gain an outage or where our various repair techniques prove ineffective - for example leaks from Littlebrook 400kV substation represents 10% of our UK losses alone.			
Type(s) of innovation involved	Radical	Project Benefits Rating	Project Residual Risk	Overall Project Score
		20	-7	27

Expected benefits of project	**If successful this innovation challenge would not only reduce our carbon footprint, but would enable National Grid to lead on this technology, minimise revenue costs due to leaks.**		
Expected timescale of project	**1 Year**	**Duration of benefit once achieved**	**8 years**
Probability of success	**95%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£1,034,186**
Potential for achieving expected benefits	**Uncertain although cross fertilisation of ideas from the Pipeline Maintenance Centre (PMC) could lead to a break through. In addition application of recently developed Electric Power Research Institute (EPRI) capture technology could provide a stop gap solution via gas capture.** **This initial feasibility phase will further establish the likely success.**		
Project progress **[Year to End of March 2013]**	**Current progress to date:** • **Prototype capture system has been designed but the production costs are higher than expected therefore the manufacturer has been asked to review the current proposals.** • **The initial gas tests on the gas reclaimed from the carbon have been received however for accuracy the experiment is being re-run just to confirm the data.** • **National Grid's PMC and Asset Engineering have engaged with the current leak sealing contractors to improve the current products and sealing techniques employed on transmission assets.** • **PMC have engaged with the original equipment manufacturer to discuss alternative sealing technology such as welding however due to the complications associated with these types of processes it is envisaged that no output will be received for 10 months.** • **Discussions have been opened with our current gas supplier to review and improve the current service to include residual gas and reclamation gas storage systems and the initial meetings are very positive.**		
Collaborative partners			
R&D provider	**University of Liverpool**		

Project Title	Temporary Oil Containment		
Project Engineer	Ruth Hooton, Chris Parks		
Description of project	The project will deliver a proven method for the deployment of a temporary oil containment storage facility (temporary is defined as up to 5 years) that will give National Grid a greater degree of flexibility in the delivery of transformer replacement schemes. It will provide a means to mitigate temporarily heightened risks at a site by strategically deploying a National Spare Transformer to a site where it would not normally be stored. The identified risks are (i) the failure of a transformer during a geomagnetically induced currents (GIC) peak; and (ii) system outage planning or other constraints that mean we may not be able to replace an asset that has reached a state requiring replacement in the desired timeframe.		
Expenditure for financial year	Internal £21k External £83k Total £103k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£103k	Projected 2013/14 costs for National Grid	£25k
Technological area and/or issue addressed by project	Where a transformer needs to be stored (even on a temporary basis) the applicable specification is National Grid TS 2.20 which requires that a National Spare Transformer be stored in a reinforced concrete Oil Retaining Area that is sufficient "to provide an effective life in excess of 40 years". The oil retaining area must incorporate a drainage system that allows for water to escape without allowing oil to seep into the water course. The cost of this permanent solution is of the order of £750k and takes around 8 months (from design) to implement following the decision to build it. The proposed system constructs the Oil Retaining Area (tank) from a geo-membrane sheet, held together with pre-stressed aluminium sections. The geo-membrane is designed to resist weathering, ultraviolet light and rain as well as many chemical substances (e.g. acids, bases and hydrocarbons). It has a high resistance to tearing, piercing and abrasion. Rain water is filtered through a Filtrelec Petro-Pipe, so it does not need to be connected to an interceptor. The filters simply allow rainwater to pass through but block in the presence of hydrocarbons. In the worst case (low probability) scenario where the transformer has emptied all its oil into the bund, the Petro-Pipe has blocked and it is raining, a siphon allows the rain water sitting at the bottom of the tank to drain whilst leaving the oil in the bund. The system is covered by a 12 month warranty. The supplier's existing temporary storage tank designs are not large enough to meet National Grid specifications for oil capture and containment. It is anticipated that the proposed design will use two separate tanks, one to store the transformer and another to store the cooler banks, the two tanks will be connected by piping hence creating a sufficiently large storage capacity. Landulph Substation has been identified as an appropriate trial site as there was already a scheme in place to construct a permanent bund to store a "Solar Spare". (The plan is then to redeploy the transformer when the GIC risk has passed).		

<table>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Radical</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>20</td><td>-8</td><td>28</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Costs include a tank access staircase (for safe access and egress to the transformer) and an additional surface membrane that will sit on top of the geo-membrane (to provide a safe working surface and lower the risk of slips, trips and falls).

Operating costs are minimal – it is proposed that an annual visual check and filter change-out could be completed when the annual oil sample for dissolved gas analysis (DGA) is taken from the transformer. The filter has a simple screw on/screw off fitment.

The temporary oil containment system could also be redeployed to store transformers on other sites; whilst the geo-membrane is likely to have an asset life of 5 years, the metal structure could be reused and a new membrane added at a cost of ~£40k.

If proven, this system will allow the fast deployment of spares to sites where storage facilities are not available and therefore could provide strategic benefit to National Grid.</td></tr>
<tr><td>Expected timescale of project</td><td>1 year</td><td>Duration of benefit once achieved</td><td colspan="2">8 years</td></tr>
<tr><td>Probability of success</td><td>90%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td colspan="2">£273,582</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">Good. Similar, smaller systems have been installed by other utilities across Europe to store distribution transformers. It is considered that the proposed larger, interconnected system is feasible for the temporary storage of transmission transformers.</td></tr>
<tr><td>Project progress

[Year to End of March 2013]</td><td colspan="4">The project was divided into two sections
• Laboratory testing of the filtration system
• Testing the oil retaining tank (bund) at a substation.

Laboratory testing of the temporary bund was carried out by Doble Power Test in association with SGS (with whom National Grid has its national oil testing contract) using filter cartridges supplied by Industrial Apparatus Consultants. The test involved filtering used transformer oil (containing dust, algae etc.), mixed with water, through the filtration unit. The filtered solution was then tested for the presence of oil with the following results:</td></tr>
</table>

PROPERTY	SAMPLE	Units	RESULT	METHOD	TECHNIQUE	LOD
EPH						
EPH (Transformer Oil)	Run Through 1st Stage Sep 1	ug/L	950	TNRCC 1006	GC-FID	10
EPH (Transformer Oil)	Run Through 1st Stage Sep 2	ug/L	1146	TNRCC 1006	GC-FID	10
EPH (Transformer Oil)	Run Through 2nd Stage Sep1	ug/L	1136	TNRCC 1006	GC-FID	10
EPH (Transformer Oil)	Run Through 2nd Stage Sep2	ug/L	1233	TNRCC 1006	GC-FID	10
EPH (Transformer Oil)	Run Through 3rd Stage Sep1	ug/L	1088	TNRCC 1006	GC-FID	10
EPH (Transformer Oil)	Run Through 3rd Stage Sep2	ug/L	1039	TNRCC 1006	GC-FID	10
EPH (Transformer Oil)	In Tank 1	ug/L	54032	TNRCC 1006	GC-FID	10
EPH (Transformer Oil)	In Tank 2	ug/L	109076	TNRCC 1006	GC-FID	10

The chromatograms for the two tanks samples were comparable with the chromatogram for the supplied reference oil standard.

SAMPLE	Units	WATER	OIL	% WATER	% OIL
VOLUME OF WATER AND OIL					
Tank 1	mL	53	4.0	93	7.0
Tank 2	mL	41	15	73	27

SAMPLE APPEARANCE

Run Through Separator samples are clear and free flowing with traces of white gelatinous solids present.

In Tank 1 & 2 contain free oil and black solids.

The filtered solution contained an average of 1.1ppm of oil. This result is below the Environment Agency's allowable levels of 5 ppm. Therefore the first section of the project has been successfully completed.

The second section of the project is part-complete. The temporary bund has been manufactured (the supplier developed a single tank design that was sized to meet National Grid's specifications) but it has not yet been deployed/tested.

The bund was not installed because of changes in the programme to deliver the transformer scheme that it was targeting. Given the relative costs associated with spare transformer procurement/ deployment versus this temporary bund; business needs were always going to drive or (as has been the case) delay completion of this R&D project.

The temporary bund is in storage at the supplier's works pending identification of a suitable scheme on which to trial it. The aim remains to use the temporary bund to store a transformer (on a temporary basis) and conclude the experiment.

Therefore a variation to this project has been proposed to ensure that the temporary bund is deployed and the trial completed. This will allow National Grid to establish proof of concept and decide if it is appropriate to recommend the use of a temporary bund solution to the business.

It has been noted that the number of suppliers offering temporary bund solutions appears to be growing; the competitive tendering of contracts for any future installations could offer further savings to the business.

Collaborative partners	
R&D provider	**Industrial Apparatus Consultants**

Project Title	Tablet Interface for an SF_6 mass flow top-up device		
Project Engineer	Carl Johnstone & Adam Baker		
Description of project	To create a sustainable template and process to reduce total cost on a solution that will use 'off the shelf' technology and open protocols with the intention that it will be scalable across multiple technologies. This project will also provide understanding of the methodology to indentify potential challenges and benefits associated with mobile data capture of test equipment This project will focus on SF_6 top-ups and will be to replace the current interface on SF_6 mass flow meters with a tablet interface which will become the one point of contact for asset management equipment onsite. This interface will control the mass flow meter during a top-up and collecting information on what asset is being topped-up. It will also be capable of sending the top-up data back to the SAM (Strategic Asset Management) system automatically instead of the operator entering the data into the system manually via a script on their laptop.		
Expenditure for financial year	Internal £4k External £9k Total £12k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£65k	Projected 2013/14 costs for National Grid	£53K
Technological area and/or issue addressed by project	National Grid have provided a highly available network to date, but moving forward the many challenges, such as environmental and Risk & Criticality, will require greater levels of information open to a greater audience in the most cost effective way. The Project will be designed to be a generic platform so that other technologies such as portable dissolved gas analysis (DGA) and partial discharge (PD) can use the project as a platform leading to one interface used for different technologies on site. This will drive a single solution to not be reliant on suppler solutions that may not meet all the requirements and will add extra training for their stand alone solution. Currently SF_6 top-ups require the person doing the top-up on		

	site to fill in a script on their laptop. This can lead to problems with data entry, filling in data in the wrong place, mis-typing data or delayed reporting of top-ups. There have even been instances where top-ups have not been reported at all. Because of this possibility of problems once a quarter two people sit down for a day and review the top-up data and correct any data errors found. **By implementing a system that collects the information at time of top-up and gives the user information to select from drop down boxes it will improve the timeliness of the reporting and also the accuracy of the data collected. Also by collecting the data directly from the mass flow to SAM it will remove errors from copying the top-up mass value from the meter to the Script.**			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score
		17	-8	**25**
Expected benefits of project	**The benefit to the business will be as follows:** • **Off the shelf interface for monitoring assets.** • **Reduced cost per unit development and capital costs.** • **One point of contact for most asset management and maintenance tasks.** • **Feeds functional requirements into IS and Business strategies.** • **Reduced cost in monitoring equipment due to reduced complexity of device.** • **Reduced training needed due to one interface being used for multiple suppliers of top-up equipment.** • **Visualisation of data though the SAM platform.** • **Automation of reporting of data back to SAM.** • **Optimise predictive planning for maintenance on site.** • **Reduce human error when reporting maintenance data back to SAM.** • **Drive policy for similar SAM technologies (portable DGA, Circuit breaker data, PD).** • **Supports the Risk and Criticality project in data accuracy.** • **Reduce external risk through mis-reporting.** **Currently each quarter, data cleanse reports are run and last year there was found to be 47+ errors in the report, totalling up to 703kg of incorrectly reported gas top-ups. The data cleansing and teaching of best practice currently accounts for 4 man days per quarter, which this project expects to reduce by 75%.**			

	Upgrading existing mass flow units to incorporate an integrated tablet interface will avoid the costs of replacing existing mass flow units. **National Grid has 150 mass flow units on the system. A new mass flow unit costs approx £15k whereas an upgrade is estimated at approx £2k. If the company decided to replace the existing units they would look to replace 20% of the units per year, which if upgraded instead of replaced, could save around £390k per annum.** **As part of National Grid longer term plan to replace office in the hand (OITH) devices on site, this project could help influence what device is chosen. This could then help to reduce cost as one device could be used for multiple tasks and the condition monitoring devices could be less complex as the interface is already onsite.**		
Expected timescale of project	2 years	Duration of benefit once achieved	**8 years**
Probability of success	80%	Project NPV = (PV benefits – PV costs) x probability of success	**£125691**
Potential for achieving expected benefits	**Although an element of risk around some of the final solution, there is a high probability of success. The first half of the project to create a fully working prototype setup including a tablet application will be completed during a university final year project. This will be completed due to the degree relying on the project completion. The second half will be completed during a student placement so will have a dedicated person working solely on the project so it can be completed in the time frame given.**		
Project progress [Year to End of March 2013]	**This project is still in progress with the student currently finishing his final year project from a software architectural view and will produce the proto-type before the target date of August. The second stage of the project is intended to happen this summer to build and deploy the beta version on a large enough population to get wide enough experience and feedback. A formal specification, if proven to be viable, will be**		

	rolled out across the population of SF_6 mass flow meters from two key suppliers.
Collaborative partners	
R&D provider	**DILO & Hertfordshire University**

Project title	Cable oil leaks & thermal data analysis			
Project Engineer	Caroline Bradley			
Description of project	This project is to examine data currently logged by National Grid and develop analysis methods to provide: • An estimate of the position and magnitude of oil leaks. • Guidance on enhanced rating methods • Techniques for the early detection of thermal anomalies and overheating.			
Expenditure for financial year	Internal £4k External £56k Total £59k	Expenditure in previous (IFI) financial years	Internal £10k External £81k Total £91k	
Total project costs (collaborative + external + [company])	£150k	Projected 2013/14 costs for National Grid	£0	
Technological area and/or issue addressed by project	Oil leaks from underground cables are damaging both environmentally and financially which impacts on the reputation of National Grid. The ability to identify oil leaks as they develop will allow National Grid to manage and its predict leaks more effectively avoiding both damage to the environment and unplanned unavailability of the network. Also improved thermal ratings techniques may allow more effective use of the transmission network, whilst avoiding overheating.			
Type(s) of innovation involved	Incremental	Project Benefits Rating 12	Project Residual Risk -2	Overall Project Score 14
Expected benefits of project	The early detection of oil leaks reduces their environmental impact. A method for locating leaks without digging sequential holes will improve cable system availability by reducing outage times, reduce repair costs and minimise the disruption to traffic. Improved understanding of distributed temperature sensing (DTS) data can enhance cable ratings, reducing costs associated with thermal constraints. Additionally it should prevent an Auckland-style blackout on the system through the early detection of thermal anomalies and prevent cables overheating avoiding expensive damage to the cables and accessories.			
Expected timescale of project	3 Years	Duration of benefit once achieved	Ongoing	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£207k	

Potential for achieving expected benefits	**The benefits are unlikely to be achieved in the short-term as the quality of the source data is poor and could not be rectified before the project was completed.** **Since the project started the server housing the oil pressure data was relocated from National Grid's Network Operations Centre to Drallim's offices. Previously the data was transmitted over the CTN network and transducers were polled every 2 hours; however communication with the servers is now via the GSM network and for reasons of cost the polling frequency has been reduced to 6 hours. This gives us rather sparse data. The situation is exacerbated by the data being 'pruned' from 4 readings a day to 1 reading a day before being archived as long-term data.** **National Grid's access to the data and the frequency of data capture will need to be reviewed before further work is considered.**
Project progress **[Year to End of March 2013]**	**The oil pressure and load current data from the Lackenby - Thornton cable circuits have been investigated. Following some pre-processing and restructuring of the data, Support Vector Machine (SVM) regression has been used to predict oil pressure in the cable system. The results obtained using the regression analysis were very promising, albeit based on limited data sets. It has been demonstrated that using this method, an expert system could give early warning with better sensitivity than existing systems. The method has the advantage that it can be implemented without taking the circuit out of service.** **Proving trials on larger data sets were not possible due to deficiencies in the available data. Ongoing developments in National Grid's capture of remote condition monitoring data mean that it should be feasible in the future to undertake a more extensive 'demonstrator' project.** **Certain issues are more difficult to address, for example the unreliability of some of the distributed temperature measurement systems and the fact that oil pressure data is held on Drallim's servers rather than National Grid's.** **Although it was not possible to fully prove the oil leak detection method, the SVM machine learning algorithms are being used in a project aimed at providing improved dynamic cable ratings to help reduce constraint costs.**
Collaborative partners	**n/a**
R&D provider	**University of Southampton**

Project title	Composite Cross Arms study
Project Engineer	Mike Fairhurst
Description of project	Task 1. Case Study Specification Upon commencement of the project, National Grid (NG), The University of Manchester (UoM) and EPL Composite Solutions Ltd (EPL) will meet and agree specifications for the L2 and L3 lattice tower cross arms. The specification will include the following. Current construction details in steel; 1. Design rules and standards for both structural and electrical performance (these being based on existing cross-arm / insulator standards); 2. Current weight and installed cost for steel cross arms / insulators, which will be used for benchmark purposes. The specification will also include the required life time, handling techniques, maintenance practices, installation characteristics etc that may be essential or useful to take into account during the design process. This specification will be used as a reference document through the course of this and any future phases of the project to ensure that the final product is fit for purpose and satisfies the requirements of NG. Task 2. Techno-Economic Benefits Of The Case Studies Given that the uptake of this technology would rely on the development of an economic case, it is essential that this is considered within this phase of work. UoM and EPL will provide to NG the benefits that can result from the composite cross-arm. This information will be largely based on work already presented to NG with some refinements based on recent work. It is anticipated that while UoM and EPL will contribute to this task with engineering support, the bulk of this work must be undertaken by NG who can cost the potential benefits of the technology. Task 3. Resolution Of Technical Barriers To Composite Cross-Arm Development This task aims to carry out an initial analysis of the following aspects of the composite cross-arm technology. These specific areas were all identified in the phase 1 report to NG as potential barriers to the development of the composite cross-arm technology. • Solution to allow maintenance access to conductor fittings • Selection and test of an appropriate coating technology • Selection of an appropriate pultrusion profile • Identification of a suitable shedding profile for the pultrusions • Design and fabrication of a wet test facility for the prototype • Consideration of failure mechanisms of existing composite insulators in relation to composite cross-arms • Software development for modelling of lateral loading

	• Development of method to provide co-ordination gaps It is not expected that these phases of work will be fully resolved in terms of defining the final solution by the end of this project phase. However, as a minimum, the challenges will have been more clearly defined and initial developments will have allowed potential final solutions to have been identified. For example, it is highly unlikely that a choice for the optimum silicone rubber coat will be selected in this work but the main challenges will be understood in terms of both manufacturing and electrical performance. The emphasis is therefore in the continued reduction of risk associated with the issues presented in the phase 1 report. At the end of this task, the expectation is that the additional knowledge gained will lead to a review of the three composite cross-arm design options previously presented (fully profiled, flat with insulator or lightly profiled with insulator). Task 4. Manufacture And Test Of Full-Scale Prototypes Within this task, a full-scale mechanical prototype (defined in task 1) will be manufactured and tested. EPL will design a structure that can be used to support the cross-arm for the purposes of mechanical testing. A second electrical rig will be developed that will be used in the UoM HV Laboratory for electrical testing only (this rig being relatively light-weight as it will not support significant load). The cross-arm will be designed using software developed in phase 1 of the project which will be updated to include lateral load applications and relevant commercial codes. The testing will be performed according to the specification defined in task 1. However, in terms of mechanical testing, it will check the ability of the prototype to withstand static loads only and not consider long term durability at this stage. Through the mounting of the cross-arm on the test rig (replicating a tower) and by the inclusion of a conductor fitting allowing the installation of a length of conductor, electrical tests will assess the ability of the cross-arm to withstand AC, lightning and switching voltages. An assessment of the levels of visual corona will also be carried out. Task 5. Development Of Future Project Road Map At the end of this project phase, the feasibility of a composite cross-arm should be fully established. It is therefore essential to have a future project road-map that builds on the proposal previously presented to National Grid. This task of work will be carried out by EPL and UMIP (the University of Manchester Intellectual Property Company). Ways to include the alliance partners of NG and cooperation with other organizations such as Hydro Quebec and EPRI will be discussed in terms of the remaining research and development phases of this work.

Expenditure for financial year	Internal £5k External £123k Total £261k	Expenditure in previous (IFI) financial years	Internal £35k External £628k Total £664k

Total project costs (collaborative + external + [company])	**£1,152k**	**Projected 2013/14 costs for National Grid**	**£227k**	
Technological area and/or issue addressed by project	**Overhead line cross-arms. The use of an insulating cross-arm potentially allows the upgrading of an L3 275 kV tower to operate at 400 kV and the elimination of the insulator strings on other tower types.**			
Type(s) of innovation involved	**Tech Transfer**	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		8	**1**	**7**
Expected benefits of project	**If it proves feasible to upgrade L3 towers to 400 kV operation there are several areas of the transmission network where future generation connections, that would ordinarily require new overhead line routes to be constructed, could be accommodated by upgrading a 275 kV route to 400 kV operation, increasing its power carrying capability, thereby avoiding the need to construct a new line.**			
Expected timescale of project	**5 years**	**Duration of benefit once achieved**	**10 years**	
Probability of success	**70%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£370k**	
Potential for achieving expected benefits	**Although there is very high potential for realising the above benefits for a line uprating, there are no relevant line upratings currently planned.. Work to date has been focusing on studying the feasibility of replacing a steel L3 tower crossarm with an equivalent composite capable of operating at 400kV. Research studies, electrical and mechanical tests have been successfully carried out to confirm this application is feasible.**			
Project progress [Year to End of March 2013]	**The project to develop insulating composite cross-arms is proceeding very well. Leverage has been obtained by shared funding from SSE, NG and the University of Manchester. The University and EPL have developed all the design skills required to consider virtually any opportunity. Designs can be generated for upgrading of 132 KV or 275 kV lines, or alternatively for reducing ground clearance of existing 132 kV, 275 kV or 400 kV lines. Opportunities also exist of optimising new line capacity and minimising visual impact with this technology. New designs of towers can also be considered and the skills developed are also being accessed to support the T-Pylon project. Integrating new cross-arm designs with the opportunities presented by novel conductor technology are also improving the benefits of the technology.** **Part of the design process development has been to develop the finite element analysis (FEA) modelling capability for complicated geometries. This has led to world-class modelling and enabled the development of sophisticated stress management techniques: which has also generated a new patent application. The manufacturing processes are now well developed with a range of products now having been fabricated and installed at the St. Fergus test site.**			

The University, via its commercialisation Company UMI3, has setup a spin-out company (Arago Technology Limited) to commercialise the technology for the benefit of the electricity industry.

The 400 kV test site in St Fergus, in an Aberdeenshire SSE substation, has been designed, built, commissioned and run for several months with prototype cross-arms. The first full version of cross-arms were installed in May and are now running 24/7. Two cross-arms are installed, and each of the 8 composite insulators is being monitored for leakage current. Multiple cameras and detailed environmental monitoring equipment are also providing online data. Early results are very positive suggesting the design of the test facilities is reliable and yielding the information required.

Mechanical and electrical testing of the cross-arm continues in the laboratory and we continue to gain information and confidence in the product. The installation in the Lecht has proven the mechanical viability of the product, and will be terminated after the summer, having given two years of high wind and snow exposure.

An image of the cross-arms at the St Fergus trial is included below:

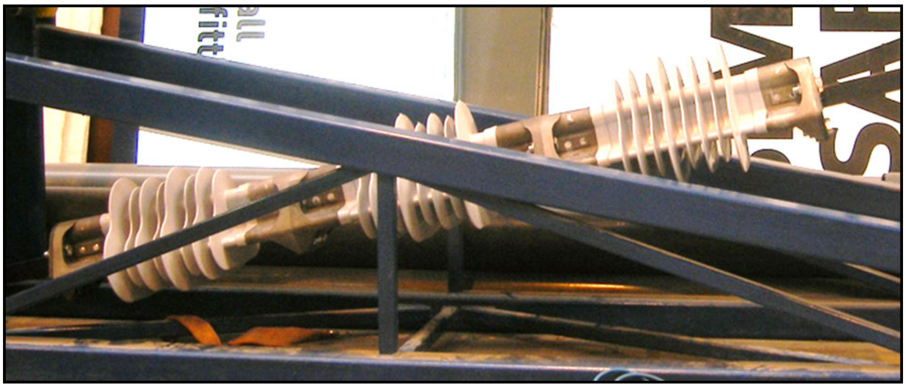
Application Of Cross-Arms For Voltage Upgrades And New Builds: Progress remains to be made on undertaking a full line study to examine the challenges that would exist in upgrading an overhead line from 275kV to 400kV operation. Analysis has shown that the challenges associated with mechanical reinforcement would reduce with the use of ACCC conductors as opposed to AAAC. In addition, the 30% load relief for broken wire situations would be achieved by the use of a small (few cm) link between an insulating cross-arm and the conductor. It remains likely that selective tower reinforcement would have to take place to upgrade an entire line. The project team remains keen to carry out a full line study with National Grid when an opportunity arises on the network.

Photo-montage of 275kV standard tower and a reduced height tower fitted with insulating cross-arms

Analysis has also been carried out with support from Balfour Beatty on the reduction in size that can be delivered by a new build line making use of insulating cross-arms. Calculations show that a 400kV tower would be reduced in height by over 30% with a 275kV tower being reduced by over 25%. This would greatly improve the visual impact of overhead line towers while also reducing costs of build.

Cross-Arm Development & Laboratory Testing: The main design change on the cross-arm that has taken place in the last twelve months has been changes to the end connection to facilitate reduced electric fields and reduce reliance on the grading rings. Along with developing the new end connection, the project team has been carrying out a range of laboratory testing to satisfy the requirements of SSE before the cross-arms are installed on the 132kV network. Where possible, testing is also being carried out at 400kV levels. A summary of the testing that has been carried out and the results that have been generated are as shown in the table below.

Compression Member Samples Being Sudden Load Release Tested

Test	Purpose	Result
		
Electrical Testing		
Interface / end connection testing (reference dry power frequency test, sudden load release, water immersion, steep fronted impulse and power frequency test)	To demonstrate that the interface between the metal end fitting and the silicone does not allow water ingress	Pass
\RIV & corona testing of full cross-arm assembly	To demonstrate that the cross-arm and associated metalwork	Pass at 132kV levels – failure of visual corona test at 400kV level.

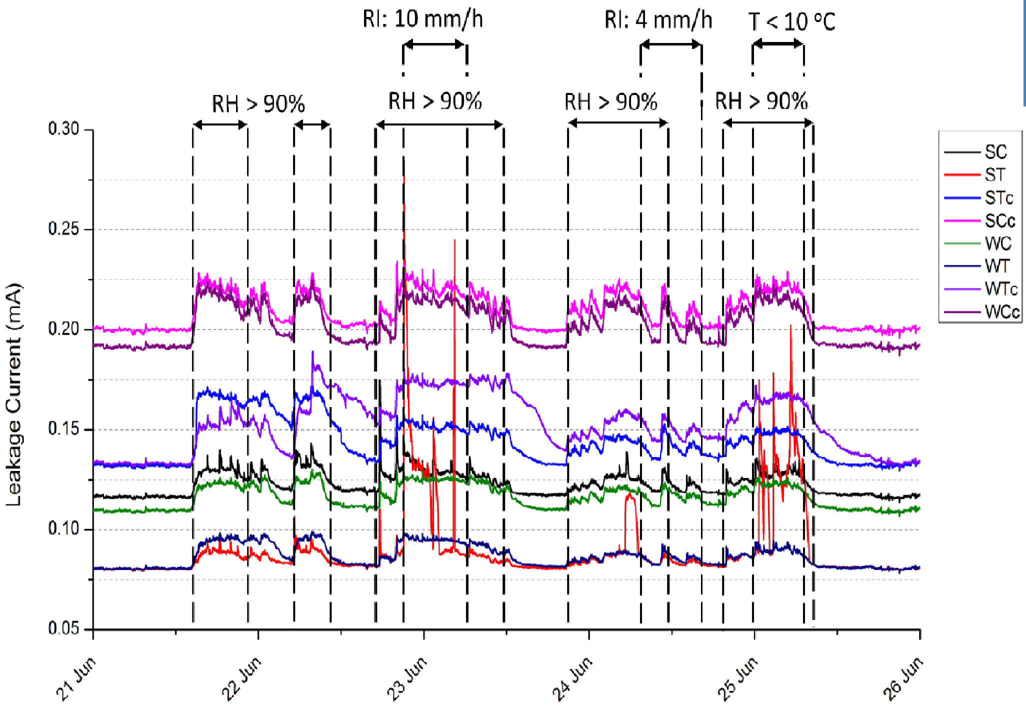
	does not produce corona / RIV	Redesign of nose connection taking place to resolve this.
Dry lightning impulse test	To confirm that the cross-arm is resistant to lightning impulses (including puncture of the silicone around the end connection)	Pass at 1425kV (the 400kV test level)
Wet power frequency test	To confirm that the cross-arm does not flashover in wet conditions	Pass at 400kV
Electric field levels	Through FEA to confirm that electric field strengths remain at acceptable levels	Pass with the exception of a high level of electric field at the grounded end of the compression members (this being due to the method of modelling used)
Dye penetration test	To confirm that moisture will not quickly travel through the core on failure of the silicone	Pass on a number of compression member sections
	Mechanical Testing	
Tensile load test	To confirm the strength of the end connections and their ability to meet broken wire loads	Pass at 200kN (designed load).
Nose connection test	To confirm the strength of the nose connection	Pass at 70kN (the maximum load permitted by the test rig).
Full cross-arm mechanical test	To subject the entire assembly to both standard and broken wire loads	Pass at 200kN (the test rig being limited to this test level and this meeting the L3 load requirement).

The results of the testing that has been carried out to date demonstrate that there is no major barrier to delivering a fully validated product for use on the 400kV system.
Field Testing: Field tests have now concluded at the test site in the Cairngorms. The test site saw four insulating cross-arms installed at a high altitude location with high wind speeds and significant levels of snow and ice. The test also saw the development of techniques for the installation and removal of insulating cross-arms from conventional towers. The test delivered a range of data to the project team but highlighted no specific risk in terms of snow / ice from the use of insulating cross-arms.

Icing Observed On The 400kV Insulating Cross-Arm Sample In The Cairngorms

In May, the two insulating cross-arms that have been installed at the St Fergus test site completed a full year of operation at 231kV (the phase to earth voltage of the 400kV system). The St Fergus test site is hosted by Scottish Hydro Electric Transmission Ltd and is in a near coastal location on the east coast of Scotland. Two insulating cross-arms are fitted at the site on a bespoke tower and are energized using a 231kV test transformer. Instrumentation monitors the current flowing in each member of the insulating cross-arm and further sensors monitor the weather and a number of other parameters with all data being stored locally and transmitted instantaneously to a live monitoring system.

Apart from two brief outages resulting from issues on the 11kV overhead line feeding the site, the trial has run continuously over the past twelve months with the cross-arms performing well in all weather conditions including the snow that fell at the site earlier this winter. The site continues to operate and gives the project team confidence in the robustness of the cross-arm design while providing valuable data. Operations will continue at the St Fergus test site in the immediate future with the project looking to relocate the test to a new location in 2014.



Example Leakage Current Data Gathered From The St Fergus Test Site

Collaborative partners	**The field trials in Scotland are funded by SSE**
R&D provider	**University of Manchester (and EPL composite solutions)**

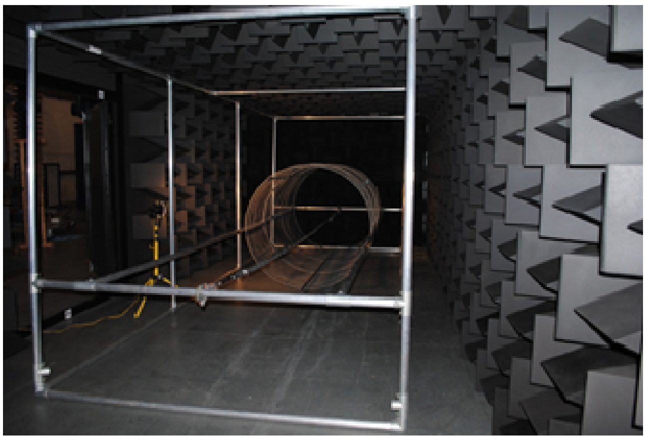
Project title	Acoustic Emissions from HV Overhead Conductors
Project Engineer	Richard Morris
Description of project	The key objective of the proposed research is aimed at understanding the causes of excessive noise from overhead line (OHL) conductors and how this might be alleviated. The aims of the project are as follows: Characterise the surface ageing processes, including corrosion, on conductors including types known as GAP, AAAC and solid aluminium: • The deposition of species (e.g. sea salt, dust, soot, pollutants, etc.) from the atmospheric environment onto the conductor surface and how these influence local processes such as pitting corrosion and hydrophobicity. • Determination of initial surface chemical state for the conductor, including hydrophobicity; how this chemistry changes as a function of environmental stresses, including: moisture, atmospheric deposition, high voltage, etc. • Determination of initial surface physical state for the conductor, this being predominantly surface roughness; the progression of roughness as a function of environmental stresses (i.e. as above). • Study interactions (if any) within the conductor, including effect of internal moisture, greasing and galvanic corrosion between steel core and aluminium conductor. • Identification of the key factors involved in physico-chemical deterioration of the surface and, hence, development of a model of surface damage with time. Characterise the corona discharge activities resulting from wet high voltage surfaces: • Audible discharge activity will be characterised in terms of volume and frequency content as a function of surface hydrophobicity, surface conductivity, surface roughness, and moisture conductivity. • The impact of the physical form of the substrate (conductor) will be determined, including conductor geometry strand size and shape and pitch. • The way in which moisture behaves macroscopically on a conductor will be determined including the impact of wind, inclination, geometry and hydrophobicity. • Measurements of force generated by discharges will also be determined. Provide a model showing the causes of excessive corona discharge leading to noise and radio frequency interference (RFI) from ‘gap’ type conductors: • The way in which complete spans of conductor might be excited to generate excessive corona discharge, noise and radio discharge from discharge activity will be modelled. • Electrodynamic behaviour resulting from the novel conductor structure will also be considered as a potential cause of the noise and radio discharge. • Generate at least one solution for to the problem of excessive corona discharge producing noise (considering requirements for existing and new installations). Working with National Grid engineers, potential remedial solutions will be identified. Information will be supplied in a form suitable for inclusion in future National Grid specification to minimise future exposure.

Expenditure for financial year	Internal £12k External £101k Total £113k	Expenditure in previous (IFI) financial years	Internal £27k External £703k Total £730k
Total project costs (collaborative + external + [company])	£843k	Projected 2013/14 costs for National Grid	£0k

Technological area and/or issue addressed by project	The environmental impact of assets is a key concern to the public and National Grid. One key aspect of this is the audible noise produced by plant. Noise resulting from high voltage overhead lines is well studied, and models exist for traditional conductors and conductor bundles. However, recent experience of Matthew GAP conductor has demanded a rethink of the fundamental, largely empirical models used. This work will challenge existing models and create data on which to base new models suitable for application on any form of conductor. This will allow novel conductors to be deployed with a clear understanding of their acoustic and electromagnetic noise emission characteristics The corrosion characteristics of new conductor materials will allow improved asset management, and the implications of ageing on acoustic noise to be determined. Additional focus is now being directed towards developing a coating solution which can be applied retrospectively to single spans as part of a strategy to manage noise issues.

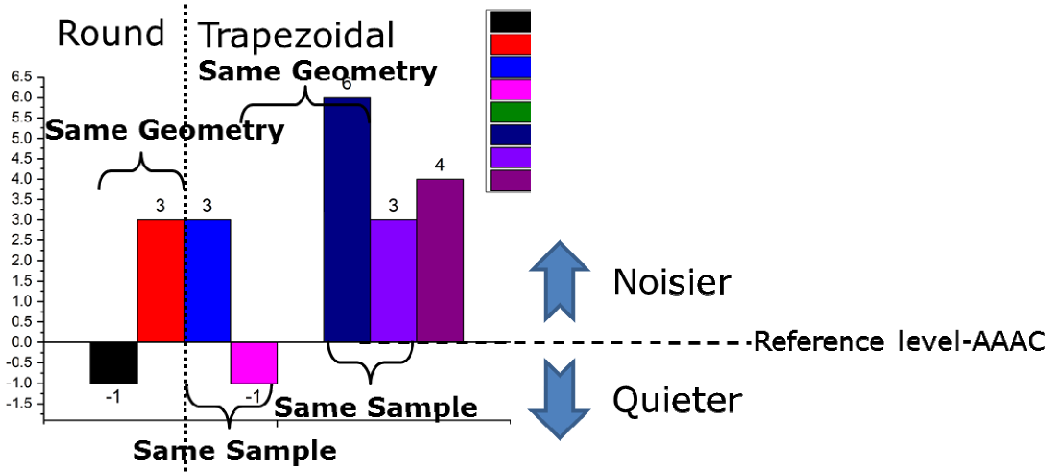
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		7	3	4

Expected benefits of project	National Grid has already spent £1.35M reconductoring just a few spans at one location on the ZO route, costs such as this could easily escalate should National Grid begin to receive more noise complaints from members of the public following reconductoring with Matthew Gap conductor. The avoidance of only one repeat event of this type would save £1.35m and more than repay the project costs as well as improving the noise issues. The avoidance of costs associated with conductor cleaning or inspection. The cleaning of conductor on only one span of the ZDA cost in the region of £25k for direct expenditure only, so future annual savings can be in the region of £12.5k per annum if one intervention can be avoided every two years, plus savings in outage planning and project management time. Avoidance of staff time taken up in managing complaints, both in liaising directly with complainants and local Environmental Health Officers, and undertaking monitoring visits. There are no clear mitigation measures available at present, so the avoidance of costs and extended time scales associated with having to resort to presently available alternatives, for example the use of triple instead of twin bundles, requiring the diverting of routes and/or rebuilding of towers, and the potential requirement to apply for Section 37 consents. The savings here can be considerable. Better specification for conductors on future schemes will reduce the need to respond reactively following complaints .

	Additional business benefits include: **A greater understanding of the processes resulting in excessive corona discharge leading to conductor noise and radio interference.** **Better modelling of conductor noise for planning and selection of appropriate conductor types and specification.** **Reduction in the number of noise issues and therefore complaints from members of public.** **Better understanding of the causes of noise and radio interference and therefore more ability to respond effectively and efficiently.** **Reduction in the number or outages (for example to carry out conductor cleaning); this may in itself generate more outage opportunities.** **Alleviate existing H&S concerns by reducing future need for manual intervention.**		
Expected timescale of project	**4 years**	**Duration of benefit once achieved**	**5 Years**
Probability of success	**60 %**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£34k**
Potential for achieving expected benefits	**Developing background knowledge to support the application of existing and new conductor technologies will be supportive of improving transmission capability and managing the environmental impact of our overhead line infrastructure. In addition this will rebuild a core competence for National Grid and its partner. the University of Manchester. It will also leave a legacy capability of laboratory-based noise and corrosion measurement on high voltage equipment for further work.**		
Project progress [Year to End of March 2013]	**The three strands of work: studying corrosion processes, modelling electric fields and acoustic energy, and measuring acoustic emission have come together to show this comprehensive approach was correct and will yield a holistic view of the processes not previously achieved.** **The project has continued broadly to plan, but a greater emphasis has been put on direct measurements of novel conductor types in the last 6 months, this is now completed. A large data set has been developed and this is now being analysed.**  **The acoustic rig has now four conditions for measuring noise output:** • **Dry** • **Manual static wetting** • **Continuous light wetting** • **Continuous heavy wetting** **Measurements are carried out over short and long term.** **It has become clear that the surface condition of individual strands is as important as strand size and geometry. Whilst it is still difficult to get details from suppliers, there is**		

also concern that products from the same suppliers can have very different properties.

Various samples, in various states of ageing, from various suppliers (including gap conductor, AAAC, ACCC/CTC, 3M, Midal, JPS) have been fully characterised. Light wetting, continuous light and heavy continuous sprays have been used. A methodology of comparison has been developed which enables direct comparison of conductor types. A part of that is illustrated below:



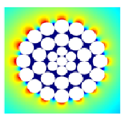
Another important conclusion is that the relative acoustic noise levels change with average surface field.

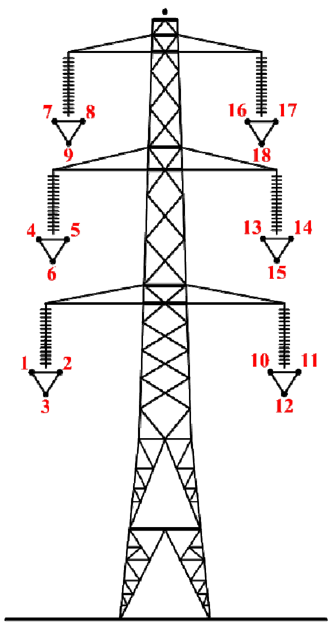
The idea of grit-blasting to improve the condition of noisy conductor has provided a mixed result. Generally there is an improvement, but the 100Hz and 200Hz and dBA signatures behave differently, and the impact is field dependent. More work is required to develop this idea.

Detailed surface field modelling is now available. Models have been completed for new conductors on traditional towers and for the T-pylon.

Since the field is not uniform over the surface of each conductor, and the circumferential field variation is different depending on the strand shape, it is proposed to develop a model which allows for that.

In the concluding period of the project the emphasis will be on developing tools to ensure the data generated is effectively transferred into the company, and to detail the basic issues behind surface condition on noise generation.





Collaborative partners	**N/A**
R&D provider	**University of Manchester**

Project title	Sustainability First - Smart Demand Forum			
Project Engineer	Craig Dyke			
Description of project	The project will investigate and build a systematic picture of GB demand-side potential from today into the 2020s with a strong focus on commercial, regulatory, customer and policy issues needing to be tackled to realise demand-side response.			
Expenditure for financial year 11/12	Internal £5k External £24k Total £29k	Expenditure in previous (IFI) financial years	Internal £7k External £0k Total £7k	
Total project costs (collaborative + external + [company])	£36k	Projected 2013/14 costs	£0k	
Technological area and/or issue addressed by project	Demand side response (DSR) is likely to be a key balancing service as wind intermittency increases and more flexible providers of balancing services are looked for. The project will build on the *Sustainability First* demand-side work (published 2010), taking on board the information and communications (I&C) sector and demand-side role of micro-gen. The work programme will essentially be carried out by Judith Ward and Gill Owen (from *Sustainability First*) with analytical work carried out by *Brattle*. Work will be coordinated via an independent cross-industry / consumer group – a *Smart Demand Forum* with representatives from all funding parties; these are expected to be Elexon, Ofgem, DECC, large users, equipment manufacturers, consumer bodies, distribution network operators (DNOs) and energy retailers.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		12	-1	13
Expected benefits of project	This project will help National Grid realise the magnitude of these services and will enable us to direct our resources to the best effect. It is our belief that demand could potentially play a significant part in the provision of Balancing Services, thereby offsetting some of the reliance on generation. By understanding what demand assets are around and will be around in the future together with an understanding of their use by customers, National Grid will be able to maximize the use of assets and avoid procuring generation whose costs are solely recovered through the provision of the service. National Grid is starting to see the benefit from such provision through the use of Responsive Load Technology employed within supermarkets that are providing dynamic response to the system. Use of this type of demand allows National Grid to reduce the number of generators held part loaded and the number of generator required on the system. Frequency response spend today is approximately £200m per year and will increase when the Security and Quality of Supply Standard (SQSS) changes to accommodate a 1800MW generation loss. It is conservatively estimated that greater knowledge in this area could lead to			

	1 or 2% of response being provided by demand rather than generation leading to a yearly saving of £0.5m to £1m. In addition and as a paying member, National Grid will have a seat at the forum and will be able to influence proceedings and provide thought leadership as well as providing the System Operator's perspective.		
Expected timescale of project	3 years	Duration of benefit once achieved	5 years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£155k
Potential for achieving expected benefits	There is a high likelihood of the project delivering its objective due to the engagement of all participants.		
Project progress [Year to End of March 2013]	The project has delivered well in the period to 31 March 2013 with the core deliverables of the project, namely a series of analytical papers, being delivered on time. The project continues to be characterised by papers that aim to explore fully and evaluate the demand for electricity and its existing capability to be flexible in response to various stimuli. The programme of papers scheduled for delivery in the forthcoming year are also expected to be in areas of interest to National Grid and are focussed on the potential and value of demand side response from a domestic consumer perspective. The papers being delivered are proving to be extremely valuable as a source of information on and analysis of the demand side of the electricity industry. There is a huge amount of industry, regulatory and governmental interest in the demand side at present. However there is very little independent authoritative research or analysis in this area. By being involved in this Sustainability First led project Natioanl Grid is able to be closely involved in their research, offering views and highlighting the publically available information on our existing balancing services that currently have demand side participation. The papers delivered in the period up to 31 March 2013 were: • Sustainability First - GB Electricity Demand - Paper 1 - Context and 2010 Baseline Data - October 2011 • Sustainability First - GB Electricity Demand Project - Paper 2 - GB Electricity Demand 2010 and 2025 - Initial Brattle Electricity Demand-Side Model - February 2012 • Sustainability First - GB Electricity Demand - DECC Electricity Demand Data Sources - Summary Note - March 2012 • Sustainability First - GB Electricity Demand - Paper 3 - What demand side services could customers offer in 2010 - Household demand- April 2012 • Sustainability First - GB Electricity Demand - Paper 4 - What demand side services can provide value to the electricity sector - June 2012 • Sustainability First – GB Electricity Demand - Paper 5 – The Electricity Demand-Side and Wider Energy Policy Developments – November 2012.		

	• Sustainability First – GB Electricity Demand – Paper 6 - What Demand Side Services Does Distributed Generation Bring to the Electricity System? – January 2013 • Sustainability First – GB Electricity Demand – Paper 7 - Evolution of Commercial Arrangements for More Active Customer and Consumer Involvement in the Demand Side – April 2013 In addition the following papers are planned in the period 1 April 2013 – 31 March 2014. • Sustainability First – GB Electricity Demand – Paper 8 – Electricity Demand and Household Consumer Issues – July 2013. • Sustainability First GB Electricity Demand – Paper 9 – GB Electricity Demand 2010 and 2025 - Updated Brattle Electricity Demand Side Model • Sustainability First – GB Electricity Demand - Paper 10 – Where Does the Electricity Demand Side Fit Into the Community Energy Picture? • Sustainability First – GB Electricity Demand - Paper 11 – How Might Innovation and Connected-Customers and Consumer Transform The Electricity Demand Side In The Longer Term? • Sustainability First – GB Electricity Demand - Paper 12 – Brining It All Together: How Can The Electricity Demand Side Play In The Electricity Market? Sustainability First has continued to schedule quarterly "Smart Demand Forum" meetings which National Grid has attended. These are primarily designed to assist in the review of draft papers, but they also allow for wider debate with a range of industry stakeholders on the present and future need for demand side response. This has again allowed National Grid to learn about others views on the potential for demand side response use in other sectors if the electricity supply industry, and in turn to share National Grid views and experiences of demand side response with the same wide group of stakeholders. In addition, Sustainability First will be holding an industry workshop on 16th May 2013. The aim of the workshop is to push forward understanding of key commercial, regulatory and policy 'enablers' and 'blockers' for active customer and consumer participation in the GB electricity demand-side. This will be an opportunity to share learning and the latest research. The outcomes are intended to help support policy development and decisions relating to demand side management. Overall the project remains positive and continues to deliver value for money.
Collaborative partners	
R&D provider	Sustainability First

Project title	Communication of system wide quantities using emerging communications technologies to enhance the stability of distributed generation (DG) during grid system disturbances. (Satellite based LoM)			
Project Engineer	Dr William Hung			
Description of project	The unreliability and instability of Loss of Mains (LoM) protection is a well know problem. This protection is designed for avoiding any embedded station being islanded but they are often triggered unnecessarily due to disconnection of generation under large system disturbance conditions (eg large loss of infeed or generation). This could be a risk to system security. As the volume of embedded plant has increased to over 6GW and is expected to continue to increase, the risk on the system could become unmanageable. It is therefore important to improve the reliability performance of this type of protection. The proposed project is to explore an alternative way of using up-to-date technology for LoM protection without jeopardising system security.			
Expenditure for financial year	Internal £4k External £14k Total £19k	Expenditure in previous (IFI) financial years	Internal £7k External £29k Total £37k	
Total project costs (collaborative + external + [company])	£99k	Projected 2013/14 costs for National Grid	£5k	
Technological area and/or issue addressed by project	This research project will investigate the potential for further improvement of the stability of distributed generation (DG) connections during system-wide events by taking advantage of existing and emerging communication technologies such as satellite and/or internet. Satellite communications may form a particularly viable solution for remote and offshore locations (where many wind farms are, or will be, installed); whereas internet could preferably be used in urban areas. Satellite communications have not been widely applied in protection systems due to the assumed limited (or rather unknown) reliability of this medium. Therefore, it is believed that in addition to the development of novel LoM methods, the key to the successful deployment of such technologies in the protection domain is the rigorous assessment of the reliability of the communication media.			
Type(s) of innovation involved	Tech Transfer	Project Benefits Rating	Project Residual Risk	Overall Project Score
		7	-6	13
Expected benefits of project	The key benefits of the project can be summarised as follows: For power system utilities – by using new improved protection methods the network operators will be able to accommodate more energy sources; For protection manufacturers – by adopting new protection methods and algorithms the manufacturers will be able to develop and offer new products meeting the demands of the future active power systems;			

	For distributed generation developers – by using new protection solutions the developers will be able to connect new energy sources at lower connection costs. For the engineering standardisation and regulatory bodies – the outcomes of this research should lead to major changes and standardisation in the fault performance of the distributed energy sources. For consumers – improved level of stability and security of electrical power delivery.		
Expected timescale of project	5 years	Duration of benefit once achieved	5 Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£18k
Potential for achieving expected benefits	The University of Strathclyde has already undertaken a substantial body of investigative research into the assessment of the existing LoM protection methods [1] and the development of new algorithms [2-3]. Moreover, the University of Strathclyde has a state of the art real time simulation facility (RTDS) for hardware testing under realistic system conditions. The above factors greatly increase the potential for meaningful, practically applicable results.		
Project progress [Year to End of March 2013]	In the second year of the project the following major milestones can be noted: 1. Technical report including a comprehensive review of the existing LoM protection methods has been prepared as part of the PhD year one review (December 2012). The report reviews 113 technical papers grouping LoM techniques into four groups: • Passive methods; • Active methods; • Communication based methods; • Hybrid methods. General methodology for the proposed communication based LoM method has been set out. 2. A significant effort was put into establishing the required software and hardware environment where the proposed LoM techniques could be developed and tested. Matlab software has been selected as a development environment in conjunction with the Real-Time Workshop toolbox. 3. A few alternative methods of communication based LoM protection have been explored and implemented in Matlab. These methods assume the availability of the reference signal measured by a phasor management unit (PMU) at the transmission level and compare it with the locally measured voltage signal. The use of both Global Positioning System (GPS) synchronised frequency and phase angle information is intended but the final version of the algorithm has not yet been established. 4. In order to accelerate the development of the working protection prototype, additional gearing for the project has been secured from the Satellite Applications Catapult (http://sa.catapult.org.uk/). The funding covers 12 months of postgraduate researcher and a purchase of dedicated protection relay development platform from Opal-RT (http://www.opal-rt.com/) with likely prospect of further		

	funding beyond the initial year. This focused prototype development project will commence in July 2013 and a research associate has already been appointed. The project will benefit from the close link with the Satellite Catapult which will deliver necessary expertise in terms of satellite communication and route to commercialisation. Technical support and practical advice from National Grid and Alstom is also a key element necessary for the successful deployment of the proposed LoM approach.
Collaborative partners	**EPSRC Doctoral Training Grant £46k** **The project partners are University of Strathclyde, Scottish and Southern, AREVA**
R&D provider	**University of Strathclyde.**

Project title	UK-wide wind power resource: Extremes and variability		
Project Engineer	David Lenaghan		
Description of project	This research activity seeks to provide National Grid with urgently required knowledge about extreme wind events, representing an essential first step in a chain of work to understand how such events affect security of electricity of supply in GB. The study will focus on three types of extreme events which are of particular interest: • high wind events, where the wind speed is in excess of the normal operating speed of a wind farm (usually 25 m/s at a turbine height of 60m above ground level); • transition and ramping events, where wind speed is rapidly changing and gusty • prolonged low wind events, where the wind speed is low for several days. Each of these possibilities will cause significant challenges to the safe and secure operation of the national electricity transmission system and it is anticipated that this project will enable analysis to be performed and knowledge gained on the frequency, severity and duration of such events. This knowledge will allow National Grid to begin adapting its business-operating model to ensure extreme scenarios are effectively managed when they occur.		
Expenditure for financial year 11/12	Internal £4k External £70k Total £74k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£171k	Projected 2013/14 costs	£97k
Technological area and/or issue addressed by project	GB and European energy policy is moving in the direction of renewables*. The key drivers are security of supply, developing the economy as well as the economic and social threat of climate change. The generation mix in the UK is therefore changing. Controllable large thermal generation units located relatively close to centres of electricity demand are being closed down. Dispersed intermittent, predominantly wind generation located towards the periphery of the network are being developed. This is radically changing the nature of system management and increasing the complexity of the problem. Knowledge about generation patterns and network flows are essential to the appropriate placement of network outages as well as balancing the cost and risks of procuring necessary energy reserves. Wind Power Forecasts (WPF) have become essential to the safe and economic operation of the GB transmission system. As experience has been gained in the process of generating forecasts and improving their accuracy it has become apparent that there is a need to understand the		

<table>
<tr><td></td><td colspan="4">risks associated with extreme meteorological events better.

* Intermittent wind generation is predicted to be approximately 30% of generation installed capacity by 2020 under the “Gone Green Scenario” http://www.nationalgrid.com/NR/rdonlyres/554D4B87-75E2-4AC7-B222-6B40836249B5/32656/ScenarioNarrative.pdf</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>9</td><td>-3</td><td>12</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">It is anticipated that the information provided by this project will assist the National Transmission System Operator to formulate a framework around the weather scenarios that have occurred in the past and hence provide guidance as to how best to manage them in the future.

National Grid seeks to improve its understanding of these events and this is recognised as an essential first step towards improving the security of network management. It will also inform decisions regarding the appropriate and economic use of reserves in the evolving and challenging wind dominated generation environment. This will lead to reduced impact on all consumers through improved reliability. Specific benefits and follow-on work are expected in the following areas:

• Industry scale: It is anticipated that this information will be used to encourage further debate with energy policy makers, regulators and other industry partners on the effects of changes as well as the equipment and system management tools required by the system operator to meet its license obligations;

• Organisation scale: It is expected that further operational strategy and development work, potentially in conjunction with academic researchers, will consider the implications of the findings and propose improvements to the business model in operational planning, scheduling and real-time operations.

• Wind-Power Forecasting (WPF) specific: Better knowledge about extreme events will increase the skill of the staff in the treatment of such events and permit further detailed studies into current WPF methods and tools.</td></tr>
<tr><td>Expected timescale of project</td><td>2 years</td><td colspan="2">Duration of benefit once achieved</td><td>ongoing</td></tr>
<tr><td>Probability of success</td><td>60%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>£102390</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">High – whilst this specific application of large “reanalysis” ** wind field data sets (see below for details) is a novel development, the scientific approach to data collection, modelling and analysis is well established. There is therefore a high confidence that the research methods proposed will be appropriate and that the research will provide valuable and original insight into these extreme weather phenomena.

<u>Footnote explanation:</u>

** Reanalysis datasets represent a state-of-the-art reconstruction of the</td></tr>
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	atmospheric circulation over the last several decades, combining observations (e.g., from satellite retrievals, ground stations, weather balloons) with a full physical weather forecast model to produce a homogenous global gridded dataset. As an example, NASA's MERRA dataset provides hourly wind-vector data at 2m, 10m and 50m above ground, covering 1979-present in grid-boxes of approximately 50x50 km (other reanalysis datasets are also available). MERRA http://gmao.gsfc.nasa.gov/merra/ Rienecker, M.M., M.J. Suarez, R. Gelaro, R. Todling, J. Bacmeister, E. Liu, M.G. Bosilovich, S.D. Schubert, L. Takacs, G.-K. Kim, S. Bloom, J. Chen, D. Collins, A. Conaty, A. da Silva, et al., 2011. MERRA - NASA's Modern-Era Retrospective Analysis for Research and Applications. J. Climate, 24, 3624-3648, doi: 10.1175/JCLI-D-11-00015.1. NCEP http://www.esrl.noaa.gov/psd/data/reanalysis/reanalysis.shtml Kalnay, E., and Coauthors, 1996: The NCEP/NCAR 40-Year Reanalysis Project. *Bull. Amer. Meteor. Soc.,* 77, 437–471.
Project progress [Year to End of March 2013]	Dirk Cannon has attended National Grid to give a presentation on the work so far at the 9 month stage. This presentation and the associated 9 month report have demonstrated that the work done so far has produced a good foundation for further work. The main objective of understanding how the re-analysis data set could best be utilised to understand the extremes of weather has been achieved. Probabilities of occurrences of high and low extremes have been calculated and are available in the report. Dirk has demonstrated that he has a good knowledge of the tools and techniques required to extract information rapidly from the data set and present it in a number of forms to convert the data into information and knowledge. The next steps are to focus on predictability and reliability of the forecasts. It is hoped that certain weather scenarios can be analysed and future forecast error can be estimated from knowledge of the weather pattern. At a simple level the likely forecast accuracy can be estimated from the complexity of the weather system. Use will be made of the historic weather data to determine under what circumstances large forecast errors commonly occur. The progress so far from Dirk has been really excellent.
Collaborative partners	
R&D provider	University of Reading

Project Title	DC Circuit Breaker Technology		
Project Engineer	Paul Coventry		
Description of project	The objective of the project is to examine and assess DC circuit breaker technologies available for use in voltage source converter (VSC) HVDC multi-terminal systems and DC grids. This in turn will ensure that National Grid is in a knowledgeable position if and when a DC breaker is required to be used on the UK network. Commencement of the research sooner rather than later will help in developing technical specifications for DC circuit breakers. It will also allow for greater time to develop the required international standards needed regarding DC breaker design and testing. These areas have been identified as needing to be addressed as part of the risk managed introduction of multi terminal VSC HVDC technology onto the transmission system and the future development of DC grids. In particular, if the UK plans on developing truly economical and secure DC grids, a thorough understanding of both the operation and the application of DC breakers will be required. The project will deliver reports on the results of studies and a documented set of models for use in National Grid's internal system studies. The work forms an essential step in being able to implement the technology on the transmission system. It is important that at all stages a close working relationship is maintained between National Grid engineers and University of Manchester researchers in order to ensure timely transfer of knowledge.		
Expenditure for financial year	Internal £4k External £51k Total £55k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£170k	Projected 2013/14 costs for National Grid	£55K
Technological area and/or issue addressed by project	The European Union Renewable Energy Directive has committed the UK to a target of more than 30% of electricity to be generated from renewable sources by 2020. The report 'Our electricity network' by the Electricity Networks Strategy Group (ENSG) recognised that a key technology to achieve the above aims is Voltage Sourced Converter (VSC) HVDC transmission. This is well suited to multi-terminal and HVDC Grid applications being considered for onshore and offshore network integration. A major bottleneck for wide-scale HVDC use is DC circuit breaker technology. The present solutions to fault isolation on an HVDC system is to use AC breakers and de-energise the entire DC system, see Figure 1 below. For a heavily integrated DC system, such as that envisaged as giving the lowest cost in the National Grid Offshore Development Information Statement (ODIS, 2010, 2011), this would result in an unacceptable loss of simultaneous generation as stipulated by the Security and Quality of Supply Standards (SQSS) infeed loss risk limits. DC Circuit breakers, Figure 2 below, offer a better solution to isolate a smaller faulted section of the DC network quickly, which ties in better with present AC protection philosophy. However, while the major manufacturers (ABB, Siemens, and Alstom Grid) are working on solutions, no commercial DC circuit breaker exists and breaker technology is unproven at the 500kV, 2kA level proposed for future offshore networks and DC grids. Outline documents to specify future DC products still need to be developed urgently though, as lower voltage and current prototypes are being developed by manufacturers with the intention of commercialising high voltage and current products. It is essential, therefore that an adequate understanding of the possible technologies,		

their operational characteristics and application issues be developed.

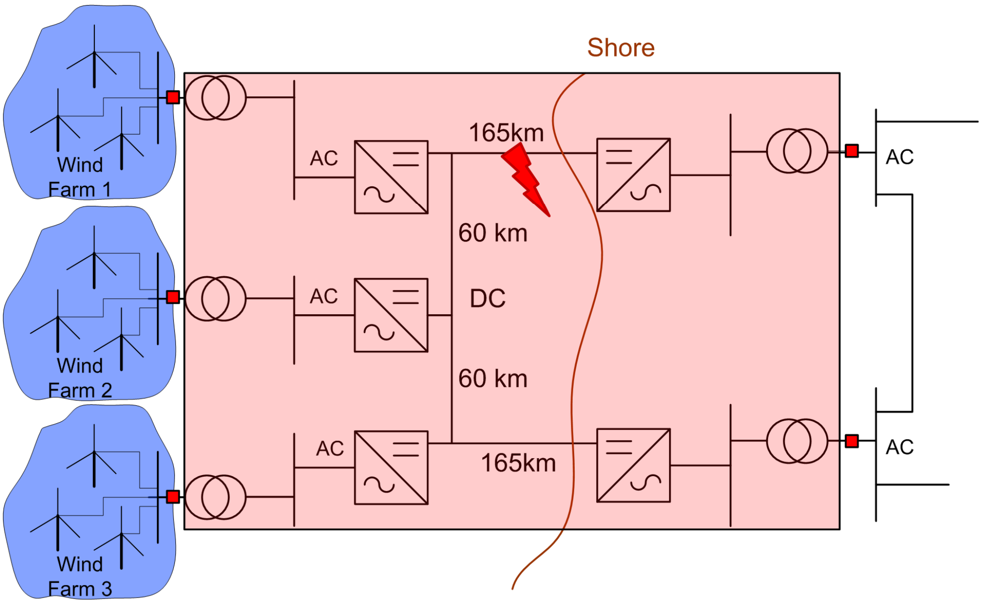


Figure 1. Example schematic for De-energised zone of Multi-terminal DC System with AC Circuit Breakers in response to DC fault

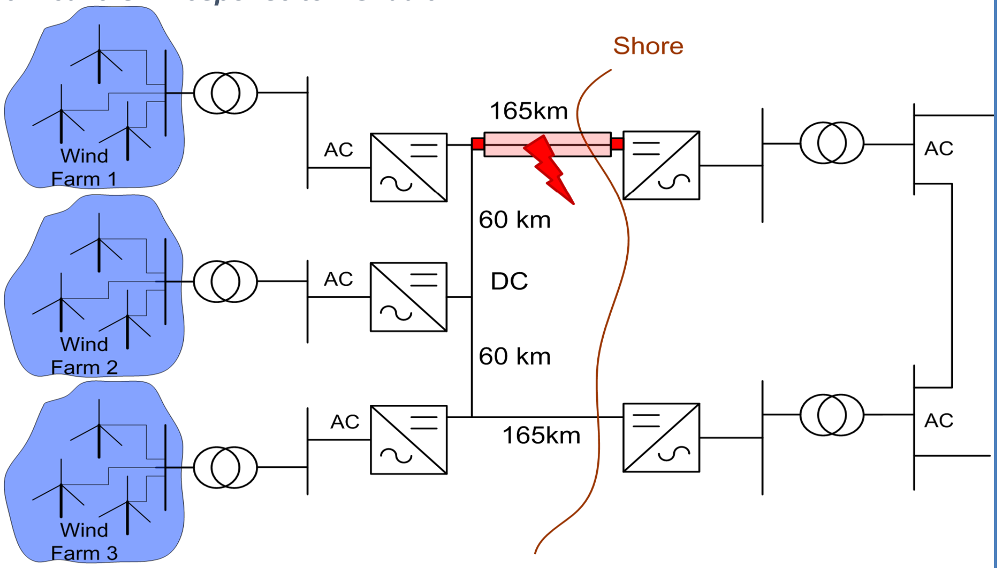


Figure 2. Example schematic for De-energised zone of Multi-terminal DC System with DC Circuit Breakers in response to DC fault

Type(s) of innovation involved	**Incremental**	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		12	**-5**	**17**
Expected benefits of project	**The proposed work forms part of the risk managed introduction of multi-terminal VSC HVDC onto the transmission system and the future development of DC grids. VSC HVDC has not previously been implemented on the UK transmission system and multi-terminal VSC has not previously been implemented anywhere. No DC circuit breakers at the required voltage of 500kV and 2kA are commercially available. Present industrial demonstrators have reached 80kV. The last 'full scale' tests on DC circuit breakers in the 1970's and 1980's used designs that are too slow for use with voltage-source HVDC, and required that current be limited by converter action, a facility that is**			

	not available with VSC-HVDC designs. It is essential therefore to understand the physical limits and potentials of DC circuit breaker technology and the limits of their potential physics of operation places on the DC and AC systems. The proposed work is intended to identify application issues associated with the technology and allow control measures to be evaluated. Failure to identify and manage such issues ahead of commissioning might have severe implications for operation of future multi-terminal DC systems. The outputs of this research will directly inform the development of any required National Grid policy documents or technical specifications relating to both DC breakers and DC grids. This research will also inform future work leading to any potential full scale trial application of DC breaker technology.			
Expected timescale of project	5 Years	Duration of benefit once achieved	8 Years
Probability of success	70%	Project NPV = (PV benefits – PV costs) x probability of success	£4,233,078
Potential for achieving expected benefits	The project is certain to increase understanding of the issues associated with application of DC circuit breakers and the integration of VSC-HVDC into the GB transmission system. There is a high likelihood that such studies will allow application issues to be identified, better understood and enable their mitigation to be evaluated. The work will significantly help with the specification of requirements for DC circuit breakers on the UK network.			
Project progress [Year to End of March 2013]	• A study summarising and analysing DC breaker technology for HVDC, VSC-HVDC and lower voltage systems such as traction has been submitted. Breaker functionality, limitations and the requirements for multi-terminal VSC-HVDC have been summarised along with the suitability of DC protection methodologies for fault location and discrimination. • A report outlining requirements and suggestions for DC breaker specification has been submitted separately.			
Collaborative partners				
R&D provider	University of Manchester			

Project Title	Matching 400kV HVAC Cable Capacity to that of Overhead Conductor Systems		
Project Engineer	Leigh Fraser		
Description of project	National Grid is continually seeking to deploy innovative solutions that deliver economic and efficient solutions that minimise its environmental and societal impact. The overall cost implications of our solutions on the consumer must be taken into account in our aim to help develop a secure, sustainable and affordable energy network. This project is intended to inform cable suppliers/manufacturers, in advance of the normal tender stages of upcoming projects, of the opportunity to proven innovative solutions that achieve the required ratings and that also give the best balance of cost, environmental impact (during and after construction) and deliverability. Innovation projects on cables are expected to be the outcomes of this project. A non-exhaustive list of potential variables includes areas such as cable cross sectional area, phase spacing, backfill, new cable technology and reducing the long-term post-fault rating duration.		
Expenditure for financial year	Internal £10k External £6k Total £16k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£16k	Projected 2013/14 costs for National Grid	£0K
Technological area and/or issue addressed by project	In 2007 the EU endorsed an integrated approach to climate and energy policy with the aim of combating climate change while delivering energy securely and affordably. The approved framework, often referred to as the 20-20-20 targets placed legally binding targets on each member state, including the UK. New Major Transmission Network Projects The connection of the new renewable and low-carbon generation, which is often located on the periphery of the transmission network, has meant that a number of new transmission circuits are required both to physically connect the new generation to the network and to increase network capacity in order to maintain an appropriate level of supply security and reliability across the main interconnected transmission system. National Grid must ensure that it, at all times, develops an efficient, economic and co-ordinated transmission network while having due regard for the impact its assets have on amenity, society and the environment in which it operates. The high outputs of the power stations and wind farms (particularly off-shore) connecting to the network means that a significant number of the new transmission circuits will require		

	very high thermal ratings. It is inevitable that, in recognising its duties outlined above, there will be a requirement for a number of underground sections in some or all of these new circuits.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		7	-7	14

Expected benefits of project

The benefits at this stage are not quantifiable as the projects that could deliver the benefits are yet to be determined.

A recent independent report *Electricity Transmission Costing Study, 31st January 2012,* which has been endorsed by the Institution of Engineering and Technology, was commissioned by the Department of Environment and Climate Change (DECC) concluded, *inter alia,* that for circuits in the report with a rating classed as "Hi" (3465 MVA) any cable section would need to consist of two cores of 3000 mm^2 XLPE cable per phase in order to achieve the required rating.

The largest cable that is currently approved for use on the National Grid system is 2500 mm^2 XLPE which is not sufficient to meet the rating requirements, the current alternative to ensuring that the post fault rating is to install 3 cores per phase. This would increase costs and have a larger environmental impact due to the size of corridor needed. Currently National Grid underground cables cost between £10.2m and £24.1M per kilometre (IET independent report) an innovative solution would avoid increased costs.

Matching Cable Ratings to Overhead Line Ratings

The co-ordination of different plant ratings in a circuit is given in PS(T) 060. This specifies that:

- The continuous rating of the cable must match or exceed the pre-fault continuous rating of the overhead line.
- The emergency rating of the cable must match the long-term post fault rating of the overhead line.

The ideal cable solution would be one that can achieve the post-fault long term rating for 24 hours when operating at the pre-fault continuous load immediately prior to the fault (synonymous with the overhead line). However, it is recognised that this may result in a solution that consequentially provides a substantial over capacity, for example, installing three cores per phase of 2500 mm^2 XLPE cable, and is therefore unlikely to be an economic or efficient solution and also has an increase in the environmental impact of our assets.

In seeking an economic solution National Grid must quantify the economic risks taken and benefits accrued in not providing the ideal solution supported with a sound understanding of any potential shortfalls of a potential solution. For example, a cable system that meets the 100% continuous rating but can only achieve the long-term post fault rating for 12 hours if the pre-

	fault load was a maximum of 75% of continuous rating may be deemed to be an acceptable trade off between investment cost and constraint risk. .		
Expected timescale of project	1 year	Duration of benefit once achieved	8 years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£-16407
Potential for achieving expected benefits	Further innovation has been identified as the output from this project.		
Project progress [Year to End of March 2013]	The project has enabled engagement with the majority of our undergrounding suppliers on National Grid's pending challenge to meet overhead line ratings for major new infrastructure projects in the future. The projects aims have been met by understanding and challenging our suppliers with regards to undergrounding innovation and to identify the parameters and installation methods that need to be fully understood with regards to ratings. The project has not only delivered engagement but has led to the instigation of further R&D focused on modelling and understanding the parameters and potential innovation to meet these new ratings intending to negate moving to 3 cables per phase and ultimately bringing financial and environmental benefits stakeholders.		
Collaborative partners	National Grid (multiple Manufacturer/supplier engagement) Manufacturers ABB Brugg Kabel Nexans NKT Cables Prysmian Cables and Systems Südkabel Manufacturer's UK agent Elmeridge Cable Service (agent for LS Cable) Supplier and installer Balfour Beatty Utility Solutions Limited		
R&D provider	National Grid		

Project Title	Application of DC Circuit Breakers in DC Grids		
Project Engineer	Paul Coventry		
Description of project	The objective of the proposed work is to understand the application issues associated with dc circuit-breakers in dc grids. The work will study the impact of dc circuit-breaker operation on the dc system, the HVDC converters and the connected ac systems. In particular, the challenges presented by protection and fault clearance in dc grids will be addressed. The work forms an essential component of the risk-managed introduction of the dc circuit-breaker onto the transmission system (in accordance with PS(T)013). The results of the work will inform technical specifications and risk-registers for the dc circuit-breaker and for the protection and control of dc grids. The project will deliver reports on the results of studies of the system behaviour and the results of experiments performed on a model (low voltage simulation) dc circuit-breaker in the analogue HVDC test facility at Cardiff University. The work complements a closely-related project at the University of Manchester which aims to study the electrical operating environment of the dc circuit-breaker and derive design and test requirements for the device itself.		
Expenditure for financial year	Internal £4k External £19k Total £23k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£150k	Projected 2013/14 costs for National Grid	£18K
Technological area and/or issue addressed by project	The European Union Renewable Energy Directive has committed the Member States to National targets for renewable energy production such that at least 20% of the EU's energy will be produced from renewable sources by 2020. Meanwhile, the creation of an internal market for energy remains one of the EU's priority objectives. The development of an interconnected internal market will facilitate cross-border exchanges in electricity and improve competition. The potential role of HVDC in integrating renewable energy generation and cross-border electricity exchanges is widely recognised and many ideas for dc grids linking the transmission systems of different countries and renewable generation are being promoted. At present, no dc circuit-breaker is commercially available and any dc fault will affect the entire dc network. A dc grid is, therefore, restricted to a single protection zone at present and the capacity of generation connected to it may not exceed the infrequent infeed loss risk limit prescribed by the Security and Quality of Supply Standard. The dc circuit-breaker is therefore an essential technology in enabling the concept of a dc grid to develop. Although the dc circuit-breaker is not yet commercially available, one supplier published developments in the area towards the end of 2011 and it is to be expected that other suppliers will follow. It is therefore timely that the research and development proposed below be initiated in order that the dc circuit-breaker could be introduced in a risk-managed way.		

<table>
<tr><td></td><td colspan="4">In contrast to an ac network, the inductance of a dc network is unable to prevent the voltage collapse that occurs in the event of a fault from propagating rapidly throughout the network. It is imperative, therefore, that the dc circuit-breaker should be able to operate fast enough to block the voltage collapse. As a consequence, the protection philosophies normally applied to an ac network are not applicable to a dc network.

One of the objectives of the proposed work is to identify the requirements of a dc circuit-breaker, including breaking current and fault clearance time. Since dc circuit-breakers will be expensive, dc fault isolation with the aid of ac circuit-breakers and fast dc isolators can be used to minimize the number of dc circuit-breakers in a dc grid. The proposed work will address fault isolation schemes and post-fault restoration of the dc grid. Various types of voltage sourced converters (VSC) will be studied and compared along with dc switchgear in fault analysis and system restoration.

The impacts of dc faults on dc and ac grids will be studied. Fault currents, dc voltages, system restoration time and interruption of power supply are some key quantities to evaluate the performance in ac grids. Grid Code requirements, loss of power transmitted between dc and ac grids, ac frequency and stability will be used to identify the ac system performance due to dc faults and corresponding fault isolation schemes with different dc switchgear.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>11</td><td>-8</td><td>19</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The dc circuit-breaker and the associated protection system are essential enabling technologies to the development of a dc grid. The proposed work forms part of the risk managed introduction of the technology onto the transmission system in accordance with PS(T)013 ‘Policy for the implementation of new technology’. The proposed work is intended to identify application issues and allow control measures to be evaluated.

The outputs of this research will directly inform the development of National Grid Risk Registers, Policy Statements and Technical Specifications relating to both dc circuit-breakers and protection for dc grids. The research will also inform the development of a proposal for a potential full scale trial application of dc circuit-breaker technology. Failure to identify and manage application issues ahead of commissioning might have severe implications and costs for operation of future multi-terminal dc systems.

The proposed work will be performed by a member of National Grid staff as a part-time PhD. The work will increase staff knowledge and build on National Grid’s relationship with Cardiff University.</td></tr>
</table>

Expected timescale of project	**5 years**	**Duration of benefit once achieved**	**Ongoing**
Probability of success	**80%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£17,839**
Potential for achieving expected benefits	**The project is certain to increase understanding of the issues associated with application of dc circuit breakers. There is a high likelihood that such studies will allow application issues to be identified, better understood and enable their mitigation to be evaluated. The work will contribute significantly to the specification of requirements for dc circuit breakers and protection for dc grids.**		
Project progress **[Year to End of March 2013]**	**A literature review has been carried out in the following main areas;** **1. Fundamentals of VSC and line-commutated converter (LCC) technologies** **2. Summary of converter faults and the protection control** **3. Summary of AC protection requirement and extending to DC protection.** **4. Development of DC circuit breakers (Research paper based)** **5. Current and future dc grids** **In addition to the above a look at the role of the DC breaker in the network to determine its functional and optional risks was briefly analysed. This will form the starting point for the next 12 months of this research.**		
Collaborative partners			
R&D provider	**Cardiff University**		

Project Title	A tool for evaluating overhead line performance under novel technology implementations			
Project Engineer	Boud Boumecid			
Description of project	Development of a computational tool to be used for the evaluation of electrical and mechanical performance of novel conductor systems on existing overhead line (OHL) networks by exploiting the full capacity of the support system.			
Expenditure for financial year	Internal £4k External £16k Total £20k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k	
Total project costs (collaborative + external + [company])	£20k	Projected 2013/14 costs for National Grid	£0K	
Technological area and/or issue addressed by project	Re-use of existing overhead lines using novel conductors to increase their thermal capacity was the subject of research by utilities for many years. Traditionally, lines were uprated by using higher ampacity standard size conductors without addressing the full potential of the existing supports which necessitates the use of bespoke conductor properties. The proposed tool will build on the work carried out by the University of Manchester in an EPSRC Supergen project. It will enable utilities to explore the use of existing and new conductor systems suitable for the type of support under consideration at very early stages of the project.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		9	-8	17
Expected benefits of project	1. The possibility of thermally uprating a line with minimal changes, modifications and/or strengthening to existing structures and foundations. To build a new line would be £1.5m per km. To refurb the line including upratings = £350k per km. This tool will contribute to the resultant potential savings. 2. The re-use of existing assets and avoiding the need to rebuild new ones. Hence, less environmental impact and spend. 3. Trial of new technologies such as high temperature low sag conductors. 4. The tool can be applied to assess the existing network in terms of the mechanical forces on the line and the suitability of the line in relation to the towers. i.e. Increasing or decreasing conductor size.			
Expected timescale of project	1 Year	Duration of benefit once achieved	8 Years	

Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£310305**
Potential for achieving expected benefits	**Success of the project is highly likely as the initial work was already undertaken under the Supergen project. This is an enhancement of previous work with high potential to be used from the industry.**		
Project progress **[Year to End of March 2013]**	**The project had a delayed start which has affected the end of the project, moving to the end of June 2013. Both partners have been informed about this change from the very beginning of the project.** **The initial target of the project was to develop the computational tool for ampacity-sag-ageing calculations further in order to enhance the computation of the algorithm and so make it more user-friendly.** **The complexity of Gap type conductor (in terms of its installation method) has changed the plan in order to allow further flexibility on re-considering a "virtual installation tension" that could be used in the case that the knee point temperature is not achieved when the GAP type conductor is installed.** **The main challenge of the project so far was to identify the properties of novel composite conductors (3M and CTC) as very often their published data are not in agreement with their conductor properties leading in some conductor performance differentiations (1%-10%). This has been addressed by using the material properties and international standard (ASTM) for lay-ratio. The error was reduced to negligible 0.0% values for CTC and up to 3% for 3M conductor technologies. However, after looking into the data provided by 3M there is still a question of accuracy of the composite core data provided, as the calculations for the 3M conductor type result in up to 3% error.** **The current key challenge is to get some profile data from OHL sections with different conductors (AAAC, ACSR, Gap) that are available from both participating companies and analyse with the tool. This will allow for a demonstration of the benefits of the tool at the very end of the project.** **The on-going work targets identifying standard installation methods for different conductor technologies, and in particular for the novel conductor composite core and Gap types, for mitigating conductor ageing. The complexity increases with the Gap type conductor as the common over-tensioning in some cases may result to over-stressing the tower structures.** **The project is currently focusing towards the finalisation of the tool and the subsequent demonstration to the partners (UK Power Networks and National Grid). In the next two months the project report will be delivered. The report will be based on additional analysis on effects derived from simulation results and it would be ideal if we could also include some specific real UK OHL sections into this analysis.**		

Collaborative partners	**UK Power Networks**
R&D provider	**University of Manchester**

Project Title	Impact of extreme events on power production at the scale of a single wind-farm		
Project Engineer	David Lenaghan		
Description of project	The aim of this research is to develop advanced models that have the capability of forecasting wind power output more accurately. The current models used by National Grid are based upon mean wind speed at the average hub height of the wind farm. It is known that this approximation leads to varying degrees of forecast error. It is anticipated that incorporating more detail about the true nature of wind flow will improve this significantly. Specifically information describing different forms of turbulence caused by convection or wake from terrain and neighbouring wind farms is believed to be very significant. The post doctoral research assistant will be encouraged to examine innovative ways to process the data provided to minimise forecast error. Suggested techniques include calculating rate of change and integrals of parameters in addition to using the explanatory variables directly. It is expected that this work will both improve the accuracy of the wind power predictions as well as improve the expression of the range and degree of uncertainty in forecast values. The effect of wind shear across a wind farm is of particular interest. The particular behaviour of individual turbines as well as the aggregated power output of the wind farm in relation to small scale and rapidly changing wind phenomena is not currently well understood.		
Expenditure for financial year	Internal £4k External £0k Total £4k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£150k	Projected 2013/14 costs for National Grid	£144K
Technological area and/or issue addressed by project	GB and European energy policy is moving in the direction of renewables. The key drivers are security of supply, developing the economy as well as the economic and social threat of climate change. The generation mix in the UK is changing. Controllable large thermal generation units located relatively close to centres of electricity demand are being closed down. Dispersed intermittent, predominantly wind generation located towards the periphery of the network are being developed. This is radically changing the nature of system management and increasing the complexity of the problem. Knowledge about generation patterns and network flows are essential to the appropriate placement of network outages as well as balancing the cost and risks of procuring necessary energy reserves. Wind power forecasts have become essential to the safe and economic operation of the GB transmission system. As experience has been gained in the process of generating		

	forecasts and improving their accuracy it has become apparent that there is a need to understand extreme meteorological events better.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		7	-6	**13**
Expected benefits of project	**Improved forecast accuracy – A 1% error in the forecast power output of the 5000MW installed wind capacity is 50MW. To ensure balance between generation and demand in real-time, this requires energy reserves to be purchased at System Buy Price or System Sell Price. Avoidance of 50MW of error this would give a cost saving of approximately £1500 per hour. Whilst specific savings may or may not be specifically attributable to this work in the future, it is clear that any effort which improves wind-power forecast accuracy will be beneficial.** **Improved understanding of situations where the model does not perform well is useful as an input into response and reserve setting procedures. This will allow greater amount of reserve to be held during periods of lower confidence in the model output. This will also allow a lesser amount of reserve to be held when there is higher confidence in the model output.** **A greater understanding of the interaction between these extreme small-scale phenomena and the architecture of wind farms will allow improved turbine designs and geographical layout to provide more consistent services and greater reliability to the grid. Findings and subsequent design changes and industry code changes which reduce the tendency of farms to cut-out under gusty conditions reducing the need for balancing reserves. As a consequence not only can an economic saving be anticipated but also a reduction in GB carbon emissions, since this reserve is currently provided by thermal generation.**			
Expected timescale of project	2 years	Duration of benefit once achieved	**8 years**	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	**£267090**	
Potential for achieving expected benefits	**Medium – it is felt that the problem and scientific methods to be used are well understood. However it is also recognised that there is a lot of work involved requiring a large amount of rigour. If successful this will provide valuable and original insight into these small scale extreme weather phenomena and their implications for effective network planning and operation.**			

Project progress [Year to End of March 2013]	**The literature review stage has been completed. This has revealed three modelling techniques that could be applied at a wind farm level. Computational Fluid Dynamics, Wake parameterization models and wind farm models. Each of these has different levels of complexity and likely simulation performance.** **The next stage of this project will focus on developing a model which estimates the wind speed, turbulence intensity and wind shear at the hub height of each individual turbine within a wind farm, based on a limited number of input parameters. This will be very useful when modelling large wind farms and the interaction between turbines within them.** **The presentation given recently shows that good progress has been made and that one of the intended areas of research is to make use of the Canopy model which has been previously used to model the air flows through urban environments. This will be adapted to model the air flows across wind farms.**
Collaborative partners	
R&D provider	**University of Reading**

<table>
<tr><th>Project title</th><th colspan="4">Live Line working Equipment</th></tr>
<tr><td>Project Engineer</td><td colspan="4">Matthew Grey</td></tr>
<tr><td>Description of project</td><td colspan="4">Live Line working was initially introduced in the 1960s and actively utilized in the 1990s. This was a high profile project and an example of how an integrated Transmission Company can use innovative Transmission Owner techniques to manage defects in a timely manner and also deliver benefits to the System Operator. These benefits are primarily around access to the system in order to ensure overhead line (OHL) defects are rectified also minimizing system outages to carry out work and so increasing system security. There are also maintenance activities that can only be undertaken using Live Line techniques. Since the introduction of Live Line in the 1990s, the system has been less constrained and deadline access more easily available (hence the decline in use). However the Transmission System is likely to become increasingly constrained over the next 5-10 years, based on forecast constraint costs, new access arrangements, continued asset investment requirements and new generation connections. Live Line Working offers significant opportunities in enabling maintenance and defect OHL work to be carried out against this background, however significant investment and commitment is required in order to re-establish previous Live Line capability.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £216k
External £158k
Total £375k</td><td colspan="2">Expenditure in previous (IFI) financial years</td><td>Internal £155k
External £1051k
Total £1206k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£1,206k</td><td colspan="2">Projected 2013/14 costs for National Grid</td><td>£305k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">Live line working in support of improved, more efficient system access in critical system areas.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>13</td><td>-4</td><td>17</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">1. Benefits of Live Line Working
▪ Live Line working would provide greater flexibility and efficiency in rectifying OHL defects, particularly as we move towards a Dynamic Asset Management model.
▪ Increased System Security due to reduced requirement for system outages.
▪ Elimination of hazards associated with dead line working due to tower climbing and earthing requirements i.e. manual handling,</td></tr>
</table>

management of induced voltages and circulating currents (this risk has significantly increased since Live Line working was first introduced).

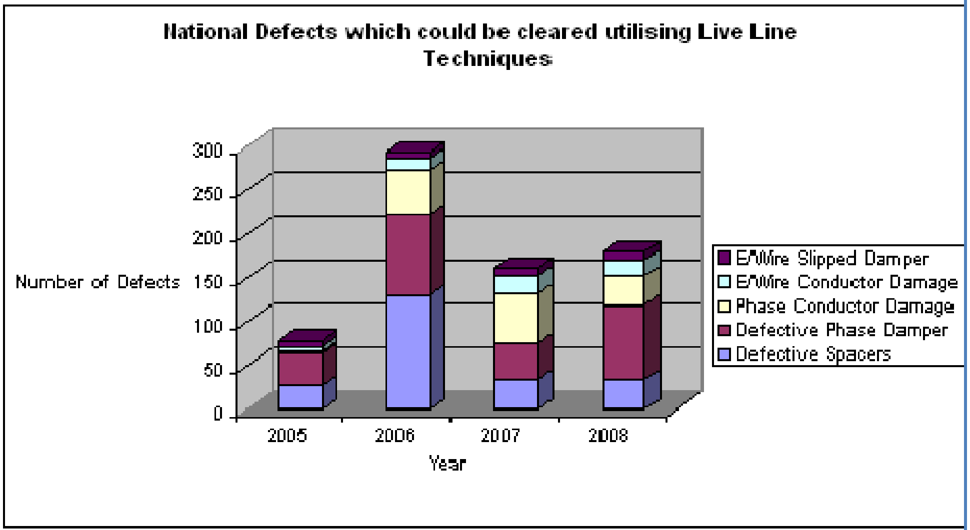
- Increased maintenance productivity levels when dealing with larger volumes, e.g. de-spacering. Typical rates of de-spacering using traditional techniques are approximately 4 - 6 span per day, whilst at the peak of Live Line use, the team were achieving up to 15 spans per day (and typically 10 spans a day).
- Additional contingency providing a further option/method of working when responding to major faults or incidents.
- There is some works that can currently only be carried out using helicopter access live line techniques (although the circuit may be de-energised), e.g. high crossing work on XL Severn River Crossing. If National Grid Live Line working is not re introduced we would be reliant on RTE to carry out this work on our behalf.
- Reduced estimated return to service time (when using helicopter access on de-energised lines); as there is no requirement to apply local earthing systems at the point of work to allow access to the circuits.
- Potential avoidance of System Outage Costs.

2. Key Drivers For Increase in Live Line Working

2.1 Current Potential Usage Of Live Line Working

Going forward due to adjustments in the capital plan, aging assets and operating cost pressure, an approach of Dynamic Asset Management will be increasingly taken. This will require having the capability to respond quickly and effectively to significant defects. Live Line working would strongly support this asset management approach, removing any system access issues, which could otherwise delay defect rectification.

In addition, based on current OHL outage defect levels, approximately £27,600 is spent per annum on monitoring of defects that could be rectified using Live Line techniques.



2.2 Short Term Transmission Access Issues

There are a number of longer term drivers that will place an upward pressure on system access:

	- **Continued high levels of asset replacement on the UK Transmission system** - **New Generation** - **Development of new Transmission Access arrangements.** **These system access issues will also be in conjunction with a greater emphasis on a dynamic asset management approach.** **Furthermore there is only one feasible provider to National Grid for Live Line work. Development of National Grid capability would introduce competition in this market and potentially allow for savings to GB consumers.** **3. Cost Benefits** **To 2015 there are a minimum of three schemes that will require helicopter access work. These include the re-conductoring of the Severn crossing, in 2014/15, which will require the dampers to be removed and then to be replaced (i.e. 2x helicopter access work). In 2011 we will be introducing our first capital scheme which will replace fittings on ACAR (Aluminium Core Alloy reinforced), as the outer aluminium strands are very soft, a trolley will not be used to access the conductor, and helicopter access will be required.** **If Live Line/helicopter access techniques were developed by National Grid, the in-house cost for this work would be approximately £40k for each scheme involving helicopter access work (i.e. £120k). If this work was to be outsourced based on previous contract costs, this would be at least £190k for each scheme (i.e. £570k, £450k more than in- house costs).** **There is also a significant amount of earthwire repair work that would normally be undertaken using Live Line helicopter techniques. Earthwire damage could be repaired typically within a day using helicopter access techniques (either deadline or live line).** **If the work had to be carried out using traditional deadline techniques, this would involve earthing (1 day for a simple circuit, 2 days for a complex circuit). It would take 2 - 3 days to lower (and then raise) the earthwire (if crossings are involved this would require the use of scaffolding or skycradle etc.), plus several hours for the actual repair. The work would therefore take anywhere between 3-5 days, depending on the complexity of the circuit, and crossings.**		
Expected timescale of project	**3 years**	**Duration of benefit once achieved**	**5 years**
Probability of success	**60 %**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£190k**
Potential for achieving expected benefits	**On target to deliver live line working during 2013 and therefore avoid potential costs to outsource the work to an external contractor. One project already planned in for completion by the National Grid live line team is the Usk River crossing in South Wales.**		

Project progress [Year to End of March 2013]	Throughout 2012/13 National Grid Overhead Lines has been working on a comprehensive R&D programme to facilitate the reintroduction of Live Line working on our overhead line (OHL) network. The main focus was placed on Live Line Work using Helicopter Access Techniques. During 2012/13 National Grid has worked closely with an aviation company to design, manufacture and install equipment for Live Line Helicopter Access work, using the National Grid helicopter. This project also includes development of a new basket to be suspended under the helicopter, a new live line insulated rope complete with terminations and new instrumentation in the helicopter. All this equipment requires all necessary certification and ongoing continuing airworthiness of all the equipment in line with European Aviation Safety Agency (EASA) regulations. The main emphasis of the project was to make use of new technology and materials to improve the environment to which the pilots and linesmen are subjected to. Significant progress has been made during the 2012/13 period. Items (i) to (vi) all went ahead successfully without any problems. Item (vii) is awaiting EASA completion and approval. i. The rope systems passed all the laboratory testing, gaining certification to IEC62192. ii. The basket design and manufacture was finalised and completed. iii. Further development on the rope system was identified, designed and completed. iv. The dates and schedule for the flight trials was agreed, culminating in the live line trial. v. Flight trials carried out at Gloucester Airfield on temporary overhead line. vi. Live trial completed on part of the National Grid OHL network. vii. Flight trials carried out witnessed by EASA flight test pilot and flight test engineer. viii. Flight test data recorded and submitted to EASA to obtain authorisation and certification to use the equipment. The flight trials commenced in January 2013 and were planned to run for about a 6 week period. The trials were split into four separate test blocks, to test individual elements, using an incremental approach to the test phases. <u>Test Block 1 – Instrument Testing</u> This involved the testing of all the instrumentation installed in the helicopter. The initial tests were carried out on the ground in the hangar, once these were completed satisfactorily the instrumentation was tested in flight with out the basket attached. The equipment tested during this phase was: • The downward facing camera systems installed in the belly of the helicopter. • The monitors mounted in the cockpit fed by the new camera system. • The load indication system (bar graph on the side of the monitors and the digital display). The load indication system was tested and

adjusted accordingly throughout the flight trials.

Test Block 2 – Load Release Testing

The next stage of the flight trials involved testing the load release mechanism and the operation/performance of the helicopter attachment and release equipment (see figure 1 & 2).

Figure 2 - Helicopter Attachment & Release Mechanism

Figure 2 – Hook attachment assembly system

Figure 3 – Rope System Successfully Released from the Helicopter

To test the load release mechanism involved the use of a 'sacrificial basket', to ensure the final working version was not damaged during this part of the trials. All the load release tests were carried out with no personnel in the basket. The basket was weighted with 200kg, to simulate two persons, several sorties were undertaken where the hook system was operated using the primary electrical release system and also the back up mechanical release system (see figure 3) to prove the system conformed with the regulatory requirements.

Test Block 3 – Human External Cargo Flight Trials

This test block was the first time the new design basket was hooked up to the helicopter. Using an incremental approach to mitigate risk as much as possible the first sorties were carried out unmanned, initially in transit, then on the temporary OHL erected at Gloucester Airfield (see figure 4) and then using two life size mannequins (see figure 5). The final stage of this test block was to put National Grid personnel in the basket, with the remit to prove the system and radio communications (see figure 6).

Figure 4 – Unmanned Basket on the Temporary OHL

Figure 5 – Two Life Size Mannequins in the Final Design basket

Figure 6 – Manned Sortie on Temporary OHL

<u>Test Block 4 – Live Line Trials on Natioanl Grid OHL System</u>

This test block involved access to the National Grid OHL network. An OHL route was chosen based on its construction and its proximity to Gloucester Airfield. The main aim of this part of the trials was to test the instrumentation in the helicopter was not affected by the close proximity to the high voltage (HV) electricity and magnetic fields. Again the same incremental approach was used to mitigate the risk as much as possible. The first part of the test block were carried out unmanned using the 'sacrificial basket' where the ropes were in contact with the live HV conductors (see figure 7), markers were used on the ropes to ensure the helicopter was in the correct position.

Figure 7 – Unmanned Live Trial Sortie

The next stage was to carry out a manned sortie onto a live conductor, this was to prove the rope and basket system and communication system (see figure 8).

	 **Figure 8 – Linesman Bonding onto Live Conductor** **The final stages of the flight trials were carried out back at Gloucester Airfield, on the temporary OHL, witnessed by the EASA Flight Test Engineer and Flight Test Pilot. All documentation collated from the flight trials is now with EASA for their review, authorisation and subsequent issue of the Supplementary Type Certificate (STC) required to use the equipment operationally.**
Collaborative partners	**N/A**
R&D provider	**Bond Aviation Group, Roblon and English Braids**

<table>
<tr><th>Project title</th><th colspan="4">Live Working in Substations (Feasibility Study)</th></tr>
<tr><td>Project Engineer</td><td colspan="4">Simon Atkin</td></tr>
<tr><td>Description of project</td><td colspan="4">Live Line working was initially introduced in the 1960s and actively utilised in the 1990s on the Overhead Lines The Transmission System is likely to become increasingly constrained over the next 5-10 years, based on forecast constraint costs, new access arrangements, continued asset investment requirements and new generation connections. Live Working in substations offers significant opportunities in enabling certain maintenance and defect work to be carried out against this background, however to provide assurance that the long term investment and commitment is workable on the existing network, a more in depth assessment of the substations is required in order to establish the criteria for live working can be met. This assessment would be undertaken by the French Electricity Company RTE who is one of the world’s experts on live working at high voltages.

Historically the high voltage equipment maintenance work in substations has been undertaken on circuits which have been de-energised, isolated and earthed. This requires longer return to service times of circuits and limited access availability. Because of the way the network is being developed and enhanced to facilitate the build of new generation and asset replacement etc it will become increasingly more constrained and hence even more difficult to get system access for essential maintenance and defect repairs.

To fully undertake live working in substations, further investment in staff training and specialist equipment is required and hence, to justify this investment, the existing substations will need to be assessed to see if the configurations used will be compatible with the established criteria for live working.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td>Internal £54k
External £90k
Total £144k</td><td colspan="2">Expenditure in previous (IFI) financial years</td><td>Internal £22k
External £10k
Total £32k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£624k</td><td colspan="2">Projected 2013/14 costs for National Grid</td><td>£446k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">Live substation working in support of improved, more efficient system access in critical system areas.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Technological substitution</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>8</td><td>2</td><td>6</td></tr>
</table>

Expected benefits of project	**Benefits of Live Substation Working** • Increased System Security and potential avoidance of System Outage Costs. • Reduced estimated return to service time due to no requirement to isolate and earth to allow access to the circuits. • Elimination of hazards associated with dead line working i.e. management of induced voltages and circulating currents (a significantly increasing risk on the network). • Additional contingency providing a further option/method of working when responding to major faults or incidents. • Ability to utilize Live Working techniques on dead (switched out only) circuits for certain work eg current transformer oil sampling, thereby enabling increased productivity with circuits switched out only with no establishment of isolation, earthing and safety document issue/cancellation ie more samples could be taken in one day. **Key Drivers to invoke Live Substation Working** • Going forward due to adjustments in the capital plan, ageing assets and operating cost pressure, an approach of Dynamic Asset Management will increasingly be taken. This will require having the capability to respond quickly and effectively to significant defects. Live working would strongly support this asset management approach, removing any system access issues, which could otherwise delay defect rectification. • There has been a significant step change in constraint costs since the start of BETTA and more so in future linked to the increase in asset replacement and construction works. Indications are that this trend will continue for the foreseeable future. • Live working techniques can be seen as another tool for constraint risk mitigation in England and Wales and there are a number of longer term drivers that will place an upward pressure on constraint costs: ▪ Continued high levels of asset replacement on the UK Transmission system. ▪ New Generation. ▪ Development of new Transmission Access arrangements. **3 Cost Benefits** ○ Long term reduction of system constraint costs in providing access to the network. ○ Justification of the future expenditure of investing in the full implementation of live substation working based on the knowledge that the existing network configurations will enable criteria for live substation working to be invoked.		
Expected timescale of project	**2 years**	**Duration of benefit once achieved**	**8 years**
Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x**	**-£109k**

		probability of success
Potential for achieving expected benefits	• The preliminary investigations into the project have indicated a high likelihood of success due to evidence of successful implementation by other utilities around the world. • National Grid's representation on the CIGRE international live working group will assist in identifying and develops best practice. • The outcome of the more intense and close up assessment of the existing substations by RTE will determine and justify the above mentioned investment to fully invoke live working in substations. • A initial meeting with H.S.E. confirmed that the justification for Live Substation working is no different than Live Line working.	
Project progress [Year to End of March 2013]	Current progress to date: • The work has predominantly been placed on hold due to the UK operating model implementation. • Calculations are currently being worked for the 400kV network to ascertain what degree of live working can be applied to the 400kV network. • Discussions with external bodies have indicated that, presently, no additional technology exists that can be employed to mechanise or improve the depth of live working within National Grid. • A presentation of the findings, along with recommendations, will be presented to the business in October 2013 and this is still on target for completion.	
Collaborative partners		
R&D provider	RTE international	

Project title	Overhead Line Robotic Technology				
Project Engineer	Michael Hannon				
Description of project	Investigate the possible solutions available for the deployment of robotic technology on overhead lines to assist with asset condition and maintenance activities. To trial world leading technology on our system to gain understanding of compatibility and potential impact.				
Expenditure for financial year 11/12	Internal £41k External £77k Total £118k		Expenditure in previous (IFI) financial years	Internal £13k External £62k Total £75k	
Total project costs (collaborative + external + [company])	£193K		Projected 2013/14 costs for National Grid	£0k	
Technological area and/or issue addressed by project	To assist with delivering the capital plan, National Grid is seeking to gain an understanding of alternative methods of inspection and maintenance of overhead line (OHL) assets. With system access being a major concern. This project aims to gain an insight into possible technologies that can be deployed and operated on live circuits. Best practice discussions have resulted in seeking out the world leaders in this technology, leading to the formation of an association with IREQ, the research institute of Hydro Quebec, Canada. IREQ have developed and deployed an overhead line inspection / maintenance Robot known as “Linescout”. This project will develop the technology with respect to the GB network.				
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score	
		22	-4	26	
Expected benefits of project	Demonstration of evolving innovative technology which would allow inspection and maintenance of OHL assets, removing the need for human intervention and system access to carry out certain tasks. Business benefits include removal of persons from towers (health and safety) and operations on live circuits. The ability to undertake inspections and maintenance tasks under live conditions provides the ability to remove the need for system access, thus protecting the business from constraint costs which, depending on system configuration and loading, could be in excess of £3M for a given outage.				
Expected timescale of project	1 year		Duration of benefit once achieved	5 years	
Probability of success	60%		Project NPV = (PV benefits – PV costs) x probability of success	£70K	

Potential for achieving expected benefits	**The potential for achieving the expected benefits is high. Hydro Quebec has already performed an initial live demonstration which was a great success whilst still indicating improvements with respect to the UK transmission network.**
Project progress [Year to End of March 2013]	**Hydro Quebec visited the UK in the autumn of 2011 to demonstrate this technology on our system both in dead and live situations.**  **Hydro Quebec undertook a demonstration of the Linescout technology on National Grid's system during September 2011. The object of this demonstration was to establish the compatibility of using the robot on the National Grid network. The trial proved a success with over fifty Managers and key personnel taking the opportunity to see and gain an understanding of the technology. Key learning points were established with reference to spacings, communication and operation of Linescout on the UK network.**  **During 2012, as part of National Grid's preparations for the London Olympics, Hydro Quebec was asked if they could demonstrate the capability of the robot in repairing a number of defects on an inaccessible Earthwire associated with a circuit feeding into an Olympic venue. This type of repair had not previously been undertaken and National Grid worked in collaboration with Hydro Quebec on a solution.** **Hydro Quebec developed a repair clip dispensing system to allow the deployment of multiple repair clips while on the conductor. Hydro Quebec**

	sent a team to the UK during June to work alongside National Grid to undertake the repair work. The work was undertaken with a successful outcome Line Scout - YouTube. Once again this demonstrated the benefits of collaboration with a world leader in robotic technology. Our next stage of development will be to gain access to the technology and work in collaboration with Hydro Quebec to develop Overhead Line inspection and repair capabilities further, providing a safe and cost effective way of managing our Overhead Lines asset base
Collaborative partners	
R&D provider	IREQ (Hydro Quebec, Canada)

Project title	Ratings of cables in tunnels (ROCIT)			
Project Engineer	David Payne			
Description of project	The objectives of this project are to: • Review the ratings methods used to design cable tunnels. • Assess existing operational data from cable tunnels, including Distributed Temperature Sensor (DTS) data. • Develop a specification for a rating method for cable tunnels installations with independent cable circuits.			
Expenditure for financial year	Internal £12k External £130k Total £142k	Expenditure in previous (IFI) financial years	Internal £23k External £152k Total £175k	
Total project costs (collaborative + external + [company])	£317k	Projected 2013/14 costs for National Grid	£0k	
Technological area and/or issue addressed by project	Rating methods employed in the design of both forced cooled and naturally ventilated cable tunnels.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		4	-3	7
Expected benefits of project	A better understanding of rating of cables in tunnels would lead to: (1) Increased use of existing tunnels for new cable installations. (2) Potential use of smaller cables for a given rating through understanding the true rating capability of cables. Optimisation of tunnel cooling systems or in some cases removing the need for any cooling system from better understanding of natural ventilation effects.			
Expected timescale of project	6 Years	Duration of benefit once achieved	2 Years	
Probability of success	70%	Project NPV = (PV benefits – PV costs) x probability of success	£78k	
Potential for achieving expected benefits	Very High. Algorithms developed under the forced ventilation stages of the project have already been used to assess cable ratings for at least two tunnel schemes.			

Project progress [Year to End of March 2013]	**2013: Algorithms developed by the University of Southampton have been integrated into the existing cable rating software used by National Grid thermal rating engineers. The integration work was carried out by Oxford Computing Consultants under the implementation phase of the scheme. The new software has been tested and has been used for a tunnel study. The Forced Ventilation phase of RoCiT is now complete.** **The natural ventilation element is almost complete and a final report is expected shortly.** **2012: Forced ventilation study completed. Implementation phase approved and algorithms developed by the University of Southampton will be integrated into existing rating software.** **Natural ventilation studies to commence shortly.** **2011: A review of existing rating methods has been carried out. Several tunnels have been visited and data gathered for further analysis. Algorithms have been developed to consider tunnels with more than one type of cable construction with forced ventilation tunnels. Further data is being gathered to verify models further.** **Progress to consider naturally ventilated tunnels has been delayed due to urgent requirement to assess ratings for live schemes.**
Collaborative partners	**None**
R&D provider	**University of Southampton.**

Project title	Oil/paper insulation HVDC performance				
Project Engineer	Gordon Wilson/Paul Jarman				
Description of project	The project will investigate the performance of the oil-paper insulation system used in HVDC transformers under a variety of electrical stress conditions. It will attempt to determine the effects of oil resistivity and other insulation condition parameters on the capability of the insulation to withstand the electrical stresses seen within HVDC transformers particularly during polarity reversal or other changes in stress.				
Expenditure for financial year	Internal £10k External £77k Total £87k		Expenditure in previous (IFI) financial years	Internal £8k External £192k Total £200k	
Total project costs (collaborative + external + [company])	£337k		Projected 2013/14 costs for National Grid	£50k	
Technological area and/or issue addressed by project	Recent work in CIGRE has highlighted that oil resistivity can greatly influence the stress distribution within an oil-paper insulation system in a DC stress environment especially during voltage changes such as polarity reversals. There have been several failures of bushings at Sellindge, during or shortly after polarity reversals, and there is evidence that the factory testing of DC transformers is inadequate to cover service conditions. A new CIGRE group is being established to look at this further and this work could usefully link to this group. The measurement of the DC conductivity of oil is not routine and a repeatable method needs to be established. This project will provide the knowledge to specify appropriate tests on new transformers and make sure that oil quality in service is maintained to suitable levels.				
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score	
		20	3	17	
Expected benefits of project	Given the likely investment in DC technology planned in the next decade it is important to have accurate knowledge and independent research to ensure that correct specification and operational choices are made to ensure long-term reliability. This project addresses the most likely cause of unreliability in HVDC transformers, the change in insulation condition between factory test and service, and its interaction with the time/stress relationship of the polarity reversal. DC transformers cost in the region of £5M per phase and failures have significant outage costs. If this research can indicate how to manage the oil in these transformers, or influence design and testing of transformers to improve reliability, then significant savings may be possible. The HVDC transformer failure rate is historically about 5-10 times worse that normal transmission units based on international figures. If we have a population of 30-50 units, which seems possible with strategic investment plans, then a failure every 1-2 years is expected unless the rate can be				

	reduced.		
Expected timescale of project	4 years	Duration of benefit once achieved	5 years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£270k
Potential for achieving expected benefits	The University of Southampton has significant expertise in measuring space charge distribution in polymer insulation systems and has recently demonstrated the technique in paper systems. They also have experience in more general measurements of the dielectric properties of oil-paper systems. It is very likely that useable results will be obtained that support the specification and operation of HVDC equipment.		
Project progress [Year to End of March 2013]	Bridge formation of cellulose particles in DC and AC fields have been observed as part of the study of pre-breakdown phenomena and computer modelling has been employed to simulate the experiments but this is proving challenging. The students successfully constructed a pulsed-electric acoustic (PEA) system last year and the method has been improved substantially to provide clearer results with reduced noise. This has enabled the study of oil/paper and the pressboard system, and the movement of space charges under DC fields and during polarity reversal and the effect of moisture and oil ageing. Experimental data thus far shows that discharge currents of aged mineral oil starts from a positive value, changes to negative value in a few seconds and then gradually approaches to zero compared with fresh oil which discharges more simply. This implies that space charge can affect electrical conduction in aged mineral oil; however, the electrical conduction mechanism in mineral oil is still not very clear. According to dielectric spectroscopy tests performed, it seems there are at least three types of charge carriers in the oil and a new model has been successfully used to simulate the dielectric spectroscopy result of mineral oil. As part of the project, the project supervisor is participating in CIGRE working group A2/D1.41 looking at oils in DC environments and has performed spectroscopic analysis of two oils as part of a round robin. This has highlighted the difficulty of studies in this area as reproducibility was poor.		
Collaborative partners			
R&D provider	The University of Southampton		

Project title	Constraint and reserve optimisation for wind generation (CROW)		
Project Engineer	Biljana Stojkovska		
Description of project	This project will deliver an assessment of the effects of including both generation and demand side reserve in real time operation and transmission capacity planning in systems with significant penetration of wind generation. The twin objectives are to: • assess how network constraints impact on allocation of spinning and standing reserve; and, • investigate whether investment in new transmission capacity may provide more efficient access to reserves needed to support cost effective integration of wind generation. This work should provide information that will be used to assess if the network planning approach should change to incorporate reserve requirements in National Grid systems with wind generation. The research will: a) Assess the importance of an approach to reserve management that dynamically optimizes the allocation of spinning and standing reserves in the presence of transmission constraints. b) Develop a methodology for quantifying the impact that generation and demand side reserve has on the transmission capacity requirements. c) Against current NGET generation and transmission reinforcement predictions for the year 2020, identify where and how much additional transmission capacity would be justified to allow generation and demand side reserve to be effectively utilized in order to reduce operational cost and support wind integration. The opportunities for generation and demand side reserve will be characterized against the predicted demand and generation background for 2020.		
Expenditure for financial year 11/12	Internal £7k External £100k Total £106k	Expenditure in previous (IFI) financial years	Internal £6k External £1k Total £7k
Total project costs (collaborative + external + [company])	£113k	Projected 2013/14 costs for National Grid	£0k
Technological area and/or issue addressed by project	Current National Electricity Transmission (NETS) System Security and Quality of Supply Standard (SQSS) network operation and planning standards do not take into consideration reserve requirements when determining network capacity. A rapid growth in wind generation in the future will significantly increase the requirement for various forms of reserve and explicit consideration of the impact on network constraints on the allocation of spinning and standing reserves across the system may become important. Similarly, increased reserve requirements may impact on the need for transmission capacity. It is expected that under some circumstances, it may be appropriate to reinforce the transmission network in order to access cost effective resources of reserve that may be in the form of generation or demand. If this work shows that there are significant benefits from incorporating		

	reserve requirements in network planning, this could be used to consider changing network design standards to include reserve requirements in addition to considering peak demand conditions and constraint costs. It is proposed to carry out this analysis on predicted generation and demand background for the year 2020 and investigate whether the inclusion of generation and demand reserve in planning methodology would deliver economics benefits. Imperial College will undertake a research project, under the supervision of Prof. Goran Strbac, to establish this understanding and to propose alternative methodologies that might be practical to be applied to a real power system.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		9	-2	11
Expected benefits of project	Currently, planning of the transmission system capacity does not consider the availability and utilisation of generation and demand reserve. The growth in wind generation will lead to an increase in reserve requirements. Identifying whether or not current operational and planning practices will deliver sufficient transmission capability for economic dispatch of reserve has the potential to deliver significant future savings. NGET estimates that reserve requirements by 2020 will be 4 times the current level which will significantly increase the reserve cost. Prior to the start of the research work the development of an optimisation tool is predicted to reduce the current £700m balancing cost by 1% per annum. This is a conservative estimate, so is very likely that once delivered, the tool will deliver much higher benefits.			
Expected timescale of project	2 year	Duration of benefit once achieved	5 years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£601k	
Potential for achieving expected benefits	There is high change of success. Imperial College have previously produced work in this area and have delivered a number of projects for NGET.			
Project progress [Year to End of March 2013]	Project achievements are the following: • The impact of reserve on GB transmission system has been investigated. • Sstanding reserves located in England and the opportunity to efficiently schedule spinning reserves without curtailing wind have been proven. • Reserve driven investment in the England-Scotland boundary has been investigated. • The effects of cross border transfers of energy and reserve between France and England have been Investigated and concluded that there will be significant benefits in enhancing the interconnector capacity. All project tasks were achieved according to the timetable with Imperial			

	College presenting very good results and conclusions.
Collaborative partners	
R&D provider	**Imperial College**

<table>
<tr><th>Project title</th><th colspan="4">Test of multi-terminal Voltage Sourced Converter (VSC) HVDC control strategies by means of an analogue test rig</th></tr>
<tr><td>Project Engineer</td><td colspan="4">Paul Coventry</td></tr>
<tr><td>Description of project</td><td colspan="4">The key objective of the proposed work is to test and demonstrate the performance of control strategies for multi-terminal voltage sourced converter (VSC) HVDC systems. The tests will be carried out by using an analogue 4-terminal VSC-HVDC test rig. The rig can be configured to a grid source (3-terminals) and an off-shore wind-farm for National Grid required configuration.

The tests using the analogue 4-terminal VSC-HVDC test rig will complement the innovation work of the Real Time Digital Simulator (RTDS) simulations to be studied by the University of Birmingham. As Cardiff University already have a 3-terminal test rig built, National Grid will be able to obtain some quick test results (in 6 months) to give us an early indication whether the control strategies proposed for a 4-terminal VSC-HVDC link are feasible, and to identify potential problems with application of the technology and inform specifications and the risk register.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td colspan="2">Internal £9k
External £28k
Total £37k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £5k
External £41k
Total £46k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£71k</td><td>Projected 2013/14 costs for National Grid</td><td>£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">Multi-terminal VSC-HVDC links are being considered by National Grid to provide additional capacity across transmission boundaries in the onshore transmission system and potentially to be used in the connection of offshore generation. Such a multi-terminal HVDC link might prove to be the most overall economic and efficient solution available when wider developments are taken into account.

National Grid has not previously implemented VSC HVDC converters on the transmission system and no multi-terminal VSC HVDC system has been implemented anywhere in the world. VSC HVDC and multi-terminal application therefore fall within the definition of new technology in accordance with PS(T)013 and their introduction onto the transmission system must be managed in a manner that takes due consideration of the risks. The tests proposed in this project form an essential part of the risk management strategy.

Cardiff University have done extensive research work in the area of multi-terminal VSC-HVDC for connecting off-shore wind-farms. They have built a 3-terminal test rig and tested the control strategies of the multi-terminal VSC-HVDC lines. The test rig can be easily added with another terminal to meet National Grid required configuration.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>7</td><td>1</td><td>6</td></tr>
</table>

Expected benefits of project	**The main benefit of the proposed work is management of the risks associated with introducing new technology onto the electricity transmission system in accordance with PS(T)013. The work is essential in order that the use of multi-terminal VSC HVDC on the transmission system may be permitted under National Grid governance to enhance the flexibility and increase the power transfer capacity. The savings in deploying such a solution in preference to less economic and efficient options is likely to be more than £100M.** **In addition to the above, any problem in application of the technology which causes delayed commissioning of the HVDC link or interruption of its operation when in service will result in costs of the order of £5m per month being incurred in constraint costs alone. The proposed work will identify potential problems before contract placement and allow the above costs to be avoided.** **This project could contribute up to 5% savings against the above costs.** **The tests of the control strategies using an analogue test rig are complementary to the RTDS simulation work and National Grid will be able to get quick test results by utilising Cardiff University's existing test rig, leveraging at least £30k against existing hardware from previous EPSRC supported work.**		
Expected timescale of project	**1 Year**	**Duration of benefit once achieved**	**5 Years**
Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**-£30k**
Potential for achieving expected benefits	**The likelihood of success of the project is high as Cardiff University have already done similar tests on their existing 3-terminal VSC-HVDC test rig successfully and acquired rich experience on the experimental platform. For this project, they need to add another terminal to build a 4-terminal VSC-HVDC test rig for the required tests.**		
Project progress [Year to End of March 2013]	**The project started on 1st February 2012. Based on the existing devices and configuration of the 3-terminal test rig, a fourth VSC was designed, connected and commissioned. Controllers and a control interface were developed for the fourth VSC and the 4-terminal test rig was operated successfully.** **Tests were performed of the 4-terminal dc network under normal and abnormal operating conditions. Normal operating conditions included start-up, shut-down, constant power control, constant voltage control, ramp changes of wind power and grid power, variable wind generation and droop control. Abnormal operation conditions included sudden disconnection of the wind farm side converter from the DC network, disconnection of a converter in power control mode, disconnection of a converter in DC voltage droop control, a transient three-phase short circuit in the AC grid and a voltage sag in the AC grid.** **The results have shown that the 4-terminal HVDC network can work properly under the various conditions tested. Based on the tests performed, a number of observations were reported and recommendations made to improve the control and operation performance of the test rig further and for future, practical multi-terminal HVDC links.**		

	The project was completed by 31 July 2012.
Collaborative partners	
R&D provider	**Cardiff University**

<table>
<tr><th>Project title</th><th colspan="3">Flexible rating options for DC operation (FRODO)</th></tr>
<tr><td>Project Engineer</td><td colspan="3">David Payne</td></tr>
<tr><td>Description of project</td><td colspan="3">This project aims to:
• Develop tools for the rating and technical assessment of high power HVDC cable options. The work will initially concentrate on cables with mass impregnated insulation.
• Provide National Grid with techniques to evaluate continuous, transient and dynamic (real time) ratings for DC cable circuits and to evaluate the options and limits for features such as current dependent voltage control.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td>Internal £5k
External £53k
Total £58k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £3k
External £43k
Total £46k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£172k</td><td>Projected 2013/14 costs</td><td>£68k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="3">National Grid is currently evaluating DC cable schemes to increase the transmission capacity of the UK network, particularly for increasing the import of electrical energy from renewable sources in Scotland.

The calculation of current ratings for DC cable is significantly more complex than that for AC cable. The rating is often determined by electric stress constraints rather than considerations of thermal ageing. Ratings are also strongly influenced by thermally induced pressure transients within the cable. In some cases the rating of the cable can be restricted by the cable being too cold.

As the normal operating voltage of the cable increases the cable can experience high levels of electric stress while the cable is hot. As the cable cools it is susceptible to electrical failure. Some manufacturers require the converter station to reduce its operating voltage if the current on the link is reduced. The implementation of these current dependent voltage control systems may help protect the cable, but this approach does not align well with the concise cable rating sheet used as part of the CUP package. This introduces an additional level of complexity for Network Operations.

Modelling the complex interactions of thermal and electrical parameters is essential if National Grid is to make a thorough assessment of tenders for HVDC cable schemes. The modelling of transient thermal conditions and the behaviour of the cable insulation under reversals of power flow will provide guidance for the development of dynamic rating algorithms and operational regimes suitable for high power HVDC cable circuits. The thermal and electrical models will be constructed in such a way that the outcomes of planned R&D work on pressure transients and partial discharge ageing can readily be incorporated at a later date.

The models will also be suitable for assessing the effect of fast polarity reversals on the cable system. This will provide guidance on more flexible operation of existing and future HVDC links. In some circumstances the opposite scenario will apply (a cable link where the direction of power flow</td></tr>
</table>

	is rarely if ever reversed). In this case the outcomes of this project could allow restrictions on cable voltage or overload capability to be lifted; again increasing the flexibility of the link.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		13	-1	14
Expected benefits of project	Without more sophisticated time-dependent models it is not possible to carry out a full assessment of tenders for HVDC cable. As converter station and cable control systems become more sophisticated, analysis of the complex interactions between the electrical and thermal ratings are needed to ensure that DC links operate efficiently and reliably. This research project will enable tenders to be analysed to ensure that cable design is appropriate for the expected burial conditions. This will ensure that capital is invested efficiently and the risk of cable system failure is minimised. The estimated costs of a failure on a major HVDC submarine link are in excess of £15m due to the timescales to affect a cable repair.			
Expected timescale of project	2 Years	Duration of benefit once achieved	40 Years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£771k	
Potential for achieving expected benefits	The potential is high based on building on a successful record of work relating to HVDC cable systems at the University of Southampton,. • The Tony Davies High Voltage Laboratory has over 40 years of experience of using both numerical modelling and experimental work to improve cable rating calculations. • Staff at the University of Southampton have extensive experience of providing cable rating support to National Grid, particularly in the areas of numerical modelling and the provision of independent verification. • Staff at the University of Southampton have world-leading experience of the design and assessment of HVDC cables and submarine cable systems; projects involving National Grid include EFI, Basslink, NSI, BritNed and the Western HVDC Link.			
Project progress [Year to End of March 2013]	The project started with the literature review. Detailed literature reviews as well as modelling exercises have been delivered. A finite element analysis (FEA) 2D model was developed with coupled thermal and macroscopic space fields under steady state. A review of the applicability of superposition principles and relevant dynamic equations for charge injection, thermionic and field emissions as well as the transition region between the two was also done from which a technical summary of the methodology and application of the charge emission mechanics was developed. An interim report was delivered in January. The report documents a detailed rating algorithm development following a refined thermoelectric breakdown limit for steady state analysis. Relevant tests on the			

	applicability of the algorithm under various operational and environmental conditions were carried out and presented with corresponding implications. Additional deliverables were included to address concerns regarding operation of DC cables at low temperatures and contractual agreements for third party crossings.
Collaborative partners	
R&D provider	**University of Southampton**

Project title	Electromagnetic transients (EMT) in future power systems – Phenomena, stresses & modelling		
Project Engineer	Forooz Ghassemi		
Description of project	A collaborative research group is being established, made up of utilities, manufacturers and research bodies, to investigate the electromagnetic transient (EMT) interaction of renewable generation on transmission equipment. The focus of the project will be on the EMT modelling of components (transformers, cables, circuit breakers, instrument transformers etc.) to provide best practice and expert opinion on their interaction with the power system. System and plant measurements will be carried out to validate the models, which can then be used to simulate and demonstrate the power system interaction phenomena on equipment such as current inrush, harmonic penetration, resonant overvoltages, etc. The work will consider transformer modelling (both in terms of modelling expertise and laboratory facilities), and acquiring cable lengths for the purpose of model validation (complex multi-phase cables with steel armouring). In addition, a number of system studies will be performed in order to highlight special transient phenomena such as how current transformer/voltage transformer saturation may impact on protection performance. Participants will highlight their interests, for instance, EdF want to compare case studies using PSCAD and EMTP-RV packages, Statkraft would like an activity on modelling oil-filled cables, Vestas is very interested in black-box cable modelling, etc. In summary, the work will: • Develop component models to characterise the range of phenomena associated with transient conditions. • Examine the network architecture. • Validate EMT models in different simulation packages. • Disseminate the results and models to the partners.		
Expenditure for financial year 11/12	Internal £6k External £25k Total £31k	Expenditure in previous (IFI) financial years	Internal £8k External £37k Total £45k
Total project costs (collaborative + external + [company])	£106k	Projected 2013/14 costs for national Grid	£30k
Technological area and/or issue addressed by project	The future power system is going to be highly complex, integrating renewable generation, smart grids, voltage upgrades, increasing usage of long cables and HVDC. Successful implementation will require extensive computer simulations during all the planning and engineering phases. Existing simulation tools have limited accuracy for representing some critical components such as transformers and cables. The project will produce models that are sufficiently accurate and compatible with available circuit simulators, and make use of the models in system simulation studies in order to pinpoint bad configurations. There is also limited understanding of these interactions, such that development project		

	engineers and designers do not know what can cause the problems and how to avoid designing potential problems.				
Type(s) of innovation involved	**Significant**	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**	
		7	**1**	**6**	
Expected benefits of project	**The business benefit is primarily the attainment of knowledge, cross industry experience and establishing best practice in the field of electromagnetic modelling of equipment in the context of future networks. Taking a number of recent incidents into consideration it is very evident that there is generally a shortage of information and perspective on this topic.** **This work will help to facilitate the connection of £50bn of renewable generation (25GW) onto the network, through understanding the level and impact of transient voltages that will arise from these types of connections to renewable generation and designing solutions to mitigate or neutralise their occurrence. Failure to do this could, in the worst case, lead to substation equipment failure and a consequential loss of supply.** **The consortium is already formed and looking to share costs, National Grid has an opportunity to leverage funding through access to a €2.5m research programme. In addition Natioanl Grid will have the opportunity to direct, to some degree, the scope and prioritisation of work. National Grid could also build on and accelerate research on certain topics, by offering some work previously carried out namely transformer modelling (University of Manchester) and cable/transformer circuit modelling (Cardiff University).** **A range of component models will be made available for National Gris to utilise in its own EMT studies to assess the unique impact on the National Grid system.**				
Expected timescale of project	**5 years**	**Duration of benefit once achieved**	**5 years**		
Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**-£128K**		
Potential for achieving expected benefits	**There is a high likelihood of success in developing a suite of models and validation of EMT models in different packages. The valuable experience gained during the pilot will help to reduce risks significantly during the ensuing project roll out.**				

Project progress [Year to End of March 2012]	**Plan and objectives of the project have been approved by the steering committee. A tool has been produced to quantify and correct for the capacitive current effect in transformer factory no-load test results.** **A test rig with associated measurement procedure has been developed to determine the linear component of a low voltage power transformer for model validation.** **Measurement and test on a sub-sea power cable is being planned for model validation. SINTEF has planned and set up a cable system for use in model validation. The cable piece has been provided by one of the contributors in the project.** **A frequency dependent parameter model for cables has been developed and it has been shown that proximity effect is important in calculating transients. This effect is ignored by most available algorithms and transient software.**
Collaborative partners	
R&D provider	**SINTEF, Delft and others**

Project title	Improve reliability of future system by enabling integration of new generation			
Project Engineer	Ian Nuttall			
Description of project	Collaboration projects with developers and manufacturers of power plant to ensure that design of new low carbon plant (combined cycle gas turbine (CCGT), Clean Coal, Nuclear) meets minimum technical system requirements.			
Expenditure for financial year	Internal £16k External £0 Total £16k	Expenditure in previous (IFI) financial years	Internal £88k External £1k Total £89k	
Total project costs (collaborative + external + [company])	£104k	Projected costs for 13/14	£0k	
Technological area and/or issue addressed by project	This project addresses frequency response capability, load rejection and operation under power system split situation, black start capability, reactive capability and control system stability.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		11	-5	16
Expected benefits of project	The project is expected to: ❖ Provide NGET with a timely and efficient means of understanding new generation technology limitation. ❖ Reduce the impact of the new generation technology on power system security by the timely development necessary codes and standards evolved from technical knowledge.			
Expected timescale of project	6 years	Duration of benefit once achieved	For the life time of the generation plant which is between 20 and 60 Years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£28k	
Potential for achieving expected benefits	The potential for the project achieving the expected benefits is good based on the collaborative team and work to date.			

Project progress 31st March 2013	**The project to-date has been very successful in engaging a number of manufacturers of generation plant equipment with the work National Grid is doing to ensure we are well placed to meet system needs in 2020 scenarios and beyond. The early stages of the project focused on the performance of the plant in terms of reliability and robustness/stability. Latterly, focus has been on exploring innovative options from new conventional plant and the integration of new types of synchronous plant.** **It has been recognised that additional flexibility and operation at low loads to ensure the ability of some plant technologies to be synchronised and providing inertia will assist with lower system inertia conditions resulting from large volumes of wind generation with little or no inherent inertia. This has been progressed with discussions with Siemens and General Electric exploring innovative options for delivering system inertia support with a minimal environmental impact.** **The work in 2012/13 has been limited somewhat by the Electricity Market Reform as manufacturers are seeing little commitment for market participants during a sustained period of uncertainty. One area of development has been with the manufacturers of the new generation nuclear plants being proposed in the UK to help understand the plant capability and foster an understanding of the concept and importance of the GB Grid Code within this new manufacturer community.** **Carbon capture and storage (CCS) has seen very slow progression with little change or commitment being brought forward in the last year. However, there has been an announcement of the successful two pilot projects[1] and National Grid continues to keep a presence within this area of technology to ensure any future plants are designed with appropriate operational flexibility in mind.** **Overall the project has delivered benefit in terms of understanding of the challenges facing the system operator and means to discuss possible solutions which the manufacturers are able to adopt within their standard products for delivery in the UK. The work will continue within the Generator Compliance team.** **[1] Peterhead CCS Project and White Rose CCS Project**
Collaborative partners	**Including Alstom, GE, Areva, Siemens**
R&D provider	**Work supported within ENI**

Project Title	Optical fibre instrumentation embedded into tunnel segments				
Project Engineer	Matthew Ray				
Description of project	This proposal relates to the installation and the use of fibre optical cable sensors to measure bending strains in modified rings made of fibre reinforced precast segments (6 per ring) for one of the new National Grid Tunnels. The objectives are (i) To understand the actual performance of linings during and after tunnel construction. (ii) To assess any cost savings that can be made be redesigning the linings for future tunnels.				
Expenditure for financial year	Internal £4k External £53k Total £57k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k		
Total project costs (collaborative + external + [company])	£57k	Projected 2013/14 costs for National Grid	£0K		
Technological area and/or issue addressed by project	National Grid has been using tunnels to bury cables in urban areas. Cable tunnels are a large cost to National Grid, reducing this would be beneficial to the company. Reducing material is also a move towards sustainability. A recent tunnelling contract, worth approximately £200 million, forms part of the additional £5.6bn of network investment needed in the UK. The new tunnelled cable network that National Grid will build under London will help meet increased energy flows across the city. It will also support increasing electricity demand, including the new Cross-rail and the replacement of existing buried cables in London. Engineers from electricity company National Grid and tunnelling experts Morgan Est are celebrating the completion of tunnelling on a new £80m cable link from Croydon to London. The 10km tunnel broke through at the Beddington Substation site early on Tuesday morning (April 28) after almost two years of tunnelling. The tunnel is part of National Grid's investment programme to reinforce electricity transmission in the South East and will house a new 400,000 Volt (400kV) cable between existing substations at Beddington and Rowdown. The cable is required to meet the growing demand for electricity in London and the South East.				
Type(s) of innovation involved	Technological Substitution	Project Benefits Rating	Project Residual Risk	Overall Project Score	
		15	-7	22	

Expected benefits of project	The major business benefit will be made through the assessment of the tunnel designs this could present cost savings that could be made b redesigning the lining for future tunnels. These are outlined in the table below.

Comparison between 3m tunnel segmental lining thicknesses

	Existing	20mm less	40mm less
Internal diameter	3.16	3.16	3.16
External diameter	3.54	3.5	3.46
Segment thickness	0.19	0.17	0.15
Internal radius	1.58	1.58	1.58
External radius	1.77	1.75	1.73
Length of tunnel (m)	12000	12000	12000
Muck away (m3)	118047.672	115395	112772.472
Muck away cost (£)	1770715.08	1730925	1691587.08
Concrete (m3)	23983.32	21330.648	18708.12
Concrete cost (£)	3597498	3199597.2	2806218
Total cost (£)	5368213.08	4930522.2	4497805.08
Saving against existing	0	437690.88	870408.00
% saving		8.15	17.65

Assumptions:

Concrete	£150/m3
Muck away	£15/m3

New mould costs will cost between £1-1.5m, if required to replace the existing moulds, therefore the savings would only be realised after the moulds had been used on a couple of projects. Given the increased use of tunnels by National Grid savings could be made by the second utilisation of the moulds.

	In addition, due to the nature of fibre optics being both affected by temperature and strain, an optical fibre temperature cable sensor will be installed into the wall as well to enable the temperature element to be removed from the strain calculations. This provides an opportunity to test the monitoring capability of embedded Fibre optics.		
Expected timescale of project	1 Year	Duration of benefit once achieved	8 years
Probability of success	80%	Project NPV = (PV benefits – PV costs) x probability of success	£101,044
Potential for achieving expected benefits	The technology and analyst technique has a high probability of success however, there is much greater uncertainty surrounding the redesign of the tunnel lining.		
Project progress [Year to End of March 2013]	Modified fibre-optic segment moulds designs were developed by the University of Cambridge in liaison with Costain and the modified segment moulds were fabricated by the segment manufacturers, Buchans, in December 2012. The concrete segments with fibre optic cables embedded were produced by Buchans and the University of Cambridge in early 2013, and locations identified for installing 2 complete modified rings at 3 separate locations on the 4m tunnel drive to analyse strain on the tunnel lining in different soil conditions. (The first two modified rings were installed, connected up and data analysed at a location in London Clay under Regents Park on the 4m tunnel drive in April 2013).		
Collaborative partners			
R&D provider	The University of Cambridge, Costain		

Project title	Automatic Risk Based Handling of Plant Enquiries Relating to National Grid Transmission Electricity and Gas Assets			
Project Engineer	Nik Wileman			
Description of project	The proposed system will determine the appropriate response to enquiries based on querying the asset data directly and through applying an expert system rules-based approach. This intelligent web based enquiry system, incorporating damage prevention management procedures and automated responses, for individuals proposing to carry out third party work in the vicinity of National Grid buried assets resulting in: - Less likelihood of damage to assets. - Reduced consequential loss of supply or service. - Reduced safety risk for those working in or near underground assets. - Reduced safety risk to members of the general public. leading to: - Reduced direct, third party damage and societal costs. - Improved health and safety. - Reduced congestion.			
Expenditure for financial year	Internal £4k External £109k Total £112k	Expenditure in previous (IFI) financial years	Internal £19k External £120K Total £138k	
Total project costs (collaborative + external + [company])	£255k	Projected 2013/14 costs for National Grid	£0K	
Technological area and/or issue addressed by project	Delivery of an automated response system to third parties for National Grid's buried assets. Development of expert system rules based on risk and assets involved. Response will provide with maps detailing the assets at risk via Web-based portal.			
Type(s) of innovation involved	Tech Transfer	Project Benefits Rating	Project Residual Risk	Overall Project Score
		13	-6	19
Expected benefits of project	Improve standards of customer service, efficiency & consistency in responding to plant enquiries. The system is designed to mitigate risks of third party damage. Known areas of critical supply and impact on vulnerable customers can be defined and monitored for high risk works.			
Expected timescale of project	2 years	Duration of benefit once achieved	5 years	

Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£8,073**
Potential for achieving expected benefits	**The external trial is nearing completion and there is a high level of confidence in the reliability of the system and the viability of providing an external facing system for use by third parties. The expectation is that the project will realise the intended benefits.**		
Project progress [Year to End of March 2013]	**The project is progressing as per the overall plan and we anticipate externalisation of the system around the August Bank Holiday. Significant progress has been made with the approval of Business Rules & Responses documents as well as the Functional Design Document (FDD). Bi-weekly confrences with the suppliers are proving effective and monthly project management boards are providing the necessary support. Work is on-going to finalise the communication strategy but the project is is delivering a working solution.**		
Collaborative partners	**National Grid Gas Transmission, National Grid Gas Distribution**		
R&D provider	**GL Noble Denton**		

Project title	Enhanced Lubrication for National Grid HV maintenance			
Project Engineer	Pete Denyer			
Description of project	To determine the most effective modern lubricants to ensure enhanced reliability and performance, replacing obsolete, ineffective and possibly environmental harmful lubricants.			
Expenditure for financial year	Internal £26k External £23k Total £49k	Expenditure in previous (IFI) financial years	Internal £59k External £253k Total £312k	
Total project costs (collaborative + external + [company])	£361k	Projected 2013/14 costs for National Grid	£0k	
Technological area and/or issue addressed by project	Lubrication and maintenance			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		11	-1	12
Expected benefits of project	Extension of maintenance frequencies for a large proportion of National Grid high voltage equipment. Increased availability and reliability. Rationalisation of existing lubricants.			
Expected timescale of project	3 Years	Duration of benefit once achieved	3 Years	
Probability of success	35%	Project NPV = (PV benefits – PV costs) x probability of success	£412k	
Potential for achieving expected benefits	The expectations are that this project will achieve the benefits expected as good lubrication is the key to reducing maintenance costs whilst ensuring good availability and reliability. Technology in the tribology field has developed considerably and this project will ensure National Grid will use the most suitable lubricants available.			
Project progress [Year to End of March 2013]	2013: The project has now been completed and is in the process of being implemented throughout National Grid Electricity Transmission. Lubricants have been identified for each lubrication "area" and procurement arranged. The technical paper "The Development of Laboratory Screening Methods to Optimize Lubrication Maintenance of High Voltage Equipment" has now been published by the National Lubrication Grease Institute. 2012: All the work by Imperial College has now been completed. The final reports and recommendations have been received. Implementation of the			

	recommendations is being discussed internally within National Grid. A technical paper "The Development of Laboratory Screening Methods to Optimize Lubrication Maintenance of High Voltage Equipment" has been presented at the National Lubricating Grease Institute (NGLI) with significant interest: Abstract: National Grid Electricity Transmission owns and operates the high voltage transmission network in England and Wales that connects power stations to local supply networks, transmitting electrical power from the generators to the end users. The equipment used in substations may stand idle for several years, being exposed to outdoor conditions, but in the case of circuit breakers be expected to operate within milliseconds to break the circuit. The combined effects of the environment and long maintenance intervals can lead to degradation of the lubricants used on the equipment. Although component failure due to poor lubrication is extremely rare, National Grid Electricity Transmission is committed to further improvements to the maintenance protocols and this is the focus of the current paper. The paper reports the background to the problem, the analysis of main degradation mechanisms and the development of laboratory tests to assess lubrication requirements in different environments across the network. The relevant degradation mechanisms were identified as ultraviolet oxidation, long-term, low temperature volatility loss and water-washout. The most important parameter determining failure was identified as static friction which if excessively high may delay component response. Static friction results are presented for a limited number of candidate lubricants for fresh and artificially degraded samples. 2011 - A Research Associate was appointed and visited National Grid refurbishment centres and sites. All current and historic lubricants have now been identified and compared based on constituent products. Interim recommendations have been submitted for the bay refurbish program. Extensive aging tests on many greases and oils have been carried out. The aging tests have been along the lines of elevated temperature, intensive UV and water washout. Analysis has been done using an infrared spectrometer and stiction & friction tests. These tests are continuing and the results being analysed and collated into a format that will be useful to field staff. Additional work has been identified for research into spray greases.
Collaborative partners	None
R&D provider	Imperial College

Project title	Alternative Fluids for Transformers			
Project Engineer	Paul Jarman			
Description of project	This project aims to evaluate alternative fluids to use as an insulating fluid for transformers to determine if they can be used at voltages of interest to National Grid. Specifically to look at one synthetic ester and two natural ester materials. Particular emphasis will be placed on investigating dielectric performance at high voltages. Ideally the project will enable sufficient confidence to be gained to enable a trial of the fluid in an in service transformer (a trial would not be part of this project).			
Expenditure for financial year	Internal £4k External £0k Total £4k	Expenditure in previous (IFI) financial years	Internal £20k External £92k Total £113k	
Total project costs (collaborative + external + [company])	£3,757k	Projected 2012/13 costs for National Grid	£0k	
Technological area and/or issue addressed by project	Use of sustainable materials for plant and reduction of potential environmental impact on failure.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score
		6	-4	10
Expected benefits of project	Use of mineral insulating oil, as used in existing transformers, has potential disadvantages in terms of environmental compatibility, fire safety and sustainability. The use of other fluids, particularly vegetable based products, could give an alternative which could prove vital if the environmental or supply situation with existing products became unsustainable. The key environmental benefit with vegetable fluid relates to its biodegradability when compared with mineral oil. Some vegetable fluids also have a higher flash point than mineral oil and have a lower energy density when aflame making them beneficial where fire risk would have significant consequences (e.g. built up areas). In addition, ageing tests conducted by other researchers have reported that for paper impregnated with vegetable fluids, the paper lifetime could be extended. Use of vegetable oil could also contribute positively to the image of the company and more widely the electricity supply industry in adopting sustainable solutions. At the moment vegetable fluids are more expensive than mineral oil but through this project National Grid will be in a position to evaluate how to take forward if applicable.			
Expected timescale of project	4 years	Duration of benefit once achieved	5 years	
Probability of success	60 %	Project NPV = (PV benefits – PV costs) x probability of success	-£58k	

Potential for achieving expected benefits	**Results have shown that ester oils have a somewhat different behaviour to mineral oil at high voltages in highly divergent electric fields, typical of the situation where partial discharge has been initiated, but breakdown has not occurred. This would indicate that special precautions to avoid partial discharge would need to be taken in the design of very high voltage transformers for use with ester liquids. This is an important discovery and could avoid significant costs in terms of unexpected failures if the technology was to be adopted.**
Project progress [Year to End of March 2013]	**The project as originally conceived is now complete and findings have been published at a CIGRE colloquium and in a paper selected for the main CIGRE session in Paris in August 2012. The project has produced a large amount of very useful data indicating that it would certainly be feasible to use vegetable oils at high voltage, but certain precautions would need to be taken. In particular the velocity at which discharges travel in ester fluids seems to be significantly higher than in mineral oil particularly for positive polarity impulses. This means that if discharge can take place breakdown is more likely. This puts a premium on good design and discharge free operation, but shows that there is potential to use ester fluids in high voltage transformers if the benefits of low fire and environmental compatibility are compelling. There may be a good case for offshore installations where weight of oil containment and fire protection would be at a premium. In service diagnostics of the ester fluids have been shown to be possible, and although some fluids are more difficult to handle (forming a gel on contact with oxygen) these problems could have technical solutions.** **The success of this project has resulted in a trial of synthetic ester with a representative 400kV transformer insulation system to be completed this year ahead of possible demonstration at an inner city site where fire protection has the highest priority.** **Good co-operation between the partners is one very positive aspect of the project and it has proved possible to assemble a wider consortium along similar lines to look at several transformer related development areas on a 4 year program in a very cost efficient manner. The expenditure for 2012-13 has largely been in attending final project meetings and helping guide the set up of the new project.**
Collaborative partners	**EdF, Areva, EPSRC, M&I Materials, TJH2B Electricity North west, Scottish Power**
R&D provider	**University of Manchester, University of Leicester**

Project title	SuperGen – HiDEF (Highly Distributed Energy Future)		
Project Engineer	Dr William Hung		
Description of project	The Consortium will develop the analytical, sustainability and economic evaluation tools, interface technologies and coordination strategies that are required to demonstrate the credibility, test the feasibility and engineer the integrative solutions of a future power system that delivers sustainability and security through the widespread deployment of distributed energy resources (DERs) and thus contributes to national and international ambition for a low carbon future.		
Expenditure for financial year	Internal £5k External £30k Total £35k	Expenditure in previous (IFI) financial years	Internal £10k External £51k Total £61k
Total project costs (collaborative + external + [company])	£4,581k	Projected 2013/14 costs for National Grid	£0k
Technological area and/or issue addressed by project	The Highly Distributed Power Systems (HDPS) Consortium has developed plans for renewal that will demonstrate a radical vision of a highly distributed energy future that enables all end users to participate in system operation and real time energy markets and thereby more fully exploits the potential of distributed generation and active load resources to deliver a more sustainable and resilient provision of energy for the future. This Highly Distributed Energy Future (HiDEF) programme researches the essential elements of a decentralised system that could be implemented over the period 2025 & 2050, but at the same time has been structured to support the evidence base relating to key questions of current concern within the stakeholder community and in this way its relevance extends beyond the limits of its decentralised system vision. In concept, the research vision is one of decentralised resources, control and market participation extending to include end users at system extremities. This challenges the current fit-and-forget strategies for the incorporation of such small elements within the power system that fails to capture the potential added value of this distributed technology. Furthermore, this approach opens up new opportunities that are not feasible in the conventional centralised structure, such as local heat and cooling grids, or district biogas schemes. In recognising this, the consortium's scope has broadened from electrical power systems to future energy systems. This builds naturally on the extensive device based modelling work and conceptual work conducted under HDPS 1. In particular, the cell concept developed by HDPS 1 becomes the mechanism for localised management of not only electrical energy but also gas/heat/cooling and to extent energy for transportation. The HiDEF project strongly complements the research, development and demonstration activities of TSB, the Carbon Trust, ETI, industry and EPSRC. A cross-cutting systems perspective is taken by the HiDEF team, building up from detailed bottom-up modelling and systems level requirements. In this way the consortium is particularly qualified to contribute to an understanding of distributed resources and loads, their optimal coordination, and mechanisms for comprehensive integration.		

Type(s) of innovation involved	Tech Transfer	Project Benefits Rating	Project Residual Risk	Overall Project Score
		5	-4	9
Expected benefits of project	The project will help to deliver efficient highly distributed embedded generation, flexible demand and actively managed network which will improve utilization of generation capacity and optimise balancing services. This will not only optimise system operation cost but reduce CO_2 emission			
Expected timescale of project	5 years	Duration of benefit once achieved	5 years	
Probability of success	50%	Project NPV = (PV benefits – PV costs) x probability of success	-£86k	
Potential for achieving expected benefits	Medium to high likelihood of success based on current output from the consortium. Success will also depend on National Grid's engagement and direction. National Grid Electricity Transmission (NGST) has been contributing to the consortium from a transmission system perspective to ensure any development in this area will be complementary to the Smart Grid Development.			
Project progress [Year to End of March 2013]	Attended 1 HiDEF Consortium management meeting and project report workshop at the University of Strathclyde. The purpose of the meeting was to allow NGET to participate in the £4.5m project supported by utility companies and 5 universities. The key objective for NGET's involvement is to establish close collaborative work with industrial and academic partners to steer future changes to deliver efficient highly distributed embedded generation, flexible demand and actively managed networks which will improve utilization of generation capacity and optimise balancing services. This will not only optimise system operation cost but reduce CO_2 emission. Some of the key issues which NGET have raised are robustness of small embedded generation (eg inconsistent and unstable rate of change of frequency (RoCoF) operations), effect of increasing 1320 to 1800 MW contingency loss on RoCoF operation and co-ordinated strategy in smart meter based demand side management. These, if not managed correctly, could jeopardise future system supply security and quality of supply. NGET reported that the Grid Code Review Panel Large Frequency Disturbance Working Group was formed in Oct 2012. The presentation at the meeting was shared with the HiDEF WG members. The progress of the WG in rectifying the RoCoF risk was also shared. HiDEF WG members were asked to share this information with their micro-generation and photovoltaic manufacturers. NGET will continue to contribute in the Consortium and the development in the different work streams and more information can be found in the project website: SuperGEN HiDEF Website Homepage			
Collaborative partners	Approx £4.5m from EPRSC and additional utilities/companies (see link for full information).			

R&D provider	**University Consortium** **Project Manager–Prof Graeme Burt (University of Strathclyde)** **Imperial Collage, University of Oxford, Cardiff University, University of Bath, Loughborough University and University of Strathclyde.**

<table>
<tr><td colspan="2">Project title</td><td colspan="4">Non Conventional Instrument Transformers (NCIT) Pilot Project Closures</td></tr>
<tr><td colspan="2">Project Engineer</td><td colspan="4">John Fitch</td></tr>
<tr><td colspan="2">Description of project</td><td colspan="4">This R&D Project aims to deliver closure, reporting on the learning achieved and the potential whole life value benefits of 3 pilot installations of non conventional instrument transformers (NCITs), which are currently installed as shadow /non operational systems on the National Grid Electricity Transmission System. This will help formulate strategies and direction for future NCIT trials and implementations.</td></tr>
<tr><td colspan="2">Expenditure for financial year</td><td>Internal £4K
External £10K
Total £14K</td><td colspan="2">Expenditure in previous (IFI) financial years</td><td>Internal £5K
External £6k
Total £11k</td></tr>
<tr><td colspan="2">Total project costs (collaborative + external + [company])</td><td>£26K</td><td colspan="2">Projected 2013/14 costs for National Grid</td><td>£0K</td></tr>
<tr><td colspan="2">Technological area and/or issue addressed by project</td><td colspan="4">As part major construction projects in the late 1990s and early 2000s, 3 pilot installations of NCITs were installed as “shadow” systems by substation project companies to help them gain some operational experience with this new technology. These projects have since lacked a focus and any potential value output, therefore this R&D project is to manage these trials through to a mutually agreed completion and outcome, with reporting on the lessons learnt and benefits achievable. It will lead to a planned decommissioning, removal and disposal of these non-maintained assets.</td></tr>
<tr><td colspan="2" rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>9</td><td>-1</td><td>10</td></tr>
<tr><td colspan="2">Expected benefits of project</td><td colspan="4">Lessons learnt form these three pilot installations will be documented and recorded and fed into future strategy and policy changes. These will include the following:

Installation Issues
Asset Performance
Asset Reliability and Stability
Maintenance Issues
Health, Safety & Environmental Issues
Asset degradation mechanisms
Decommissioning and Disposal Issues.

Risks to the UK Electricity Transmission Network will be reduced by removal of non maintained/non operational assets connected to the high voltage system and auxiliary supplies.</td></tr>
<tr><td colspan="2">Expected timescale of project</td><td>2 year</td><td colspan="2">Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td colspan="2">Probability of success</td><td>60%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£23k</td></tr>
</table>

Potential for achieving expected benefits	**With a project focus to manage these 3 NCIT pilot installations and commitment from product suppliers, the likelihood of success in project delivery is considered high though the benefits are more uncertain.**
Project progress **[Year to End of March 2013}**	**The NCIT on Metal-enclosed switch and breaker (MSB) circuit breaker (CB) at Sundon substation (NextPhase Optical CT) trial has been taken over by Alstom GRID (from Siemens) and the trial is to continue for a short period, following installation of an anti vibration mounting kit. Final test results will be collated demonstrating any improved mechanical performance and an R&D closure report completed. The unit will then be decommissioned and removed as the NextPhase NCIT design has now been improved.** **The Alstom GRID gas insulated switchgear NCITs (Rogowski current transformer and Electronic voltage transformer) installed on a section of gas insulated busbars at Osbaldwick substation will be inspected; test results collated and a closure report written. As this site is now considered unsuitable for a future protection trial, the NCITs will be decommissioned and the prototype Merging Units and Protection Relay cubicles removed from site.** **The ABB NCIT at Trawsfynydd still requires a final inspection, the test results collated with any required forensics, prior to decommissioning and removal from the system.** **A check is to be carried out on any NCIT installation at Cottam substation.** **The above work is moving forward slowly due to issues with supplier support and site access issues. Once the final upgrades and tests have been completed and reports written, it is planned to seek outages to decommission and remove the equipment from the system where possible.** **.**
Collaborative partners	
R&D provider	**Alstom GRID & ABB**

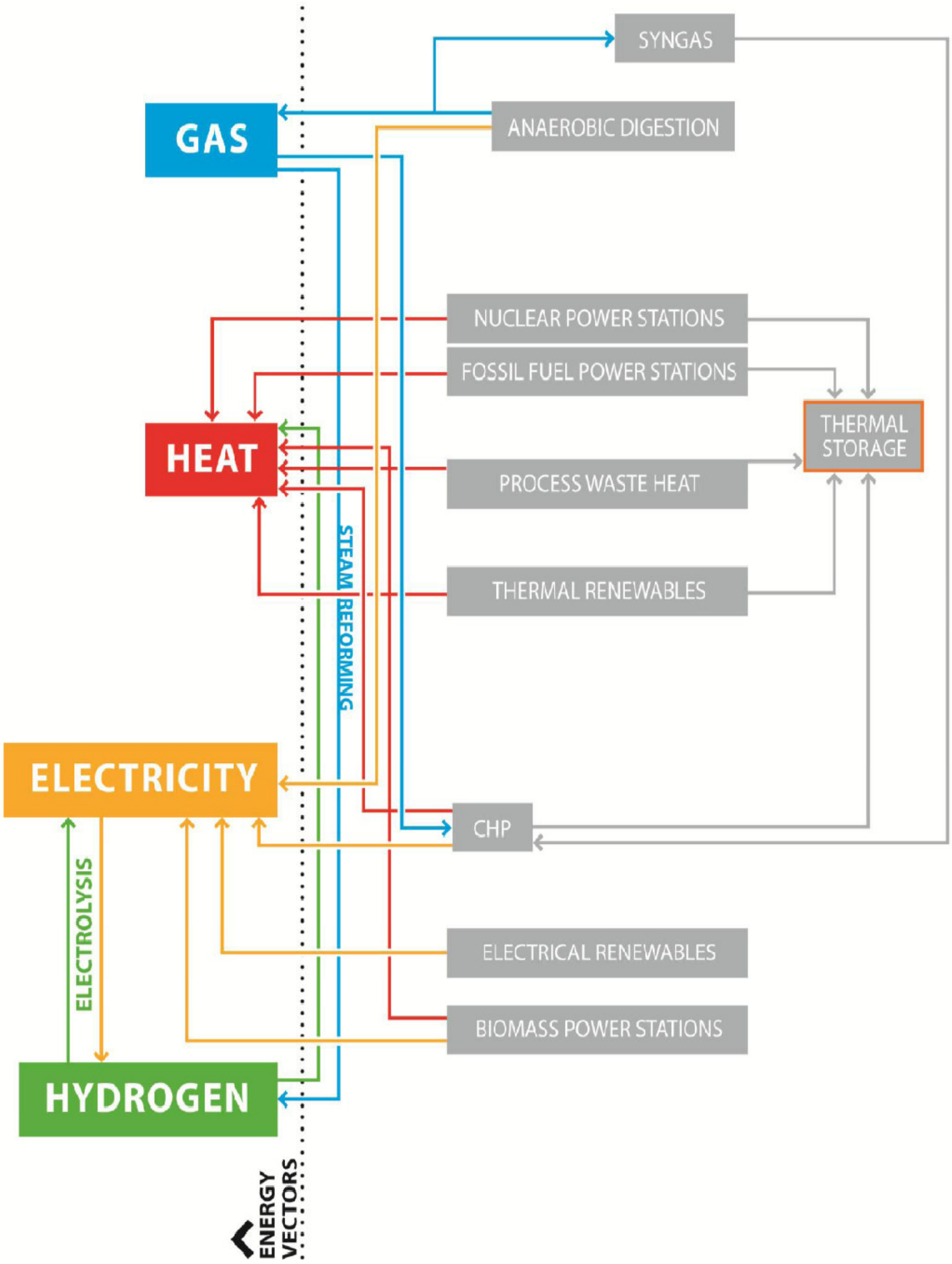
Project title	Protection and Control Roadmap		
Project Engineer	John Fitch		
Description of project	This R&D Project is to provide a set of detailed reports on the technical challenges faced by National Grid in the general areas of Protection & Control (P&C), which will clearly identify the technical and process risks faced and the options on how these may be mitigated. It will identify, review and prioritise the Protection & Control technical and asset management challenges likely to be faced by National Grid in the time frames of 2020, 2030, with a view beyond. This will help provide a common focus for existing strategies based on technical expertise and feasibility and R&D projects with timelines for implementation and also establish a further set of prioritised R&D required to manage these identified risks, leading to a clear vision and consolidated plan for implementation of future changes.		
Expenditure for financial year 11/12	Internal £7k External £29k Total £37k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£37k	Projected 2013/14 costs	£0k
Technological area and/or issue addressed by project	Clearly National Grid is entering a new phase of uncertainty in the optimum requirements for providing a "fit for purpose" protection and control solution to meet the needs of the changing transmission network. This is being driven by a need to adapt more quickly to change, to accommodate and manage the connection of intermittent wind generation at the extremities of the network, series compensation, embedded HVDC connections, offshore AC and HVDC connections and larger nuclear generation sets, together with the closure of many traditional coal fired power stations. This is leading to a situation where much larger, critical hub substations will be built requiring higher integrity P&C systems and with a further need to modify easily and extend them over significant periods of time. This will require protection and control solutions which are not only adaptable and flexible to meet the fast changing needs of the network, but need to address the consequential impacts on existing systems in older substations which may need to be progressively upgraded. There are also threats to the P&C settings and configurations process, which has traditionally resulted in well tested and fixed parameters for a fixed network, but will have to adapt in near real time to changing network configurations, load flows and fault in-feed capability. To manage this new network, new metering and monitoring requirements are emerging which are supervising the system and the connected generator technical and contracted performance as well as identifying emerging quality of supply issues. All the above are leading to new requirements for secure and protected communication channels which can support new services for wide area monitoring, protection, automation and control.		

	This R&D project will gather all this information from stakeholders in the P&C area, review situations in comparable utilities, identify the threats and challenges and propose a timeline of options and solutions that can be taken forward. This will help focus existing R&D and technical strategies towards a common goal and vision and ensure that a holistic approach is achieved addressing the future needs of the network. In addition it is expected that further R&D will be identified to gather more knowledge and experience.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		4	-7	11
Expected benefits of project	The output from this project will ensure that a common vision and strategy is produced for Protection and Control, ensuring that R&D effort is not wasted, technical strategies are focused and that short term tactical solutions are avoided. It will also ensure that the capabilities of existing and newly deployed systems are fully exploited, meeting all end user needs and avoiding the need to overlay with additional systems at a later time. The benefits will feed through into a common vision and strategy document for P&C leading to policy and specification changes. These will feed into major substation projects and asset replacement works. The benefits will include the following: - More secure transmission network with optimised P&C functionality, redundancy and performance. Safer, better protected assets and systems. Optimised CAPEX for investments and OPEX for support services and maintenance. Extended asset life with improved performance levels. Systems that can be more easily and economically changed to meet the fast changing needs of the transmission network. Sustainability – reducing rework and avoiding early asset replacement. Standardised approach – simpler, repeatable engineering, reduced spares and optimised technical support levels. Compact and repeatable designs.			
Expected timescale of project	1	Duration of benefit once achieved	8	
Probability of success	0.6	Project NPV = (PV benefits – PV costs) x probability of success	-21877	

Potential for achieving expected benefits	**This project will engage the University of Manchester senior staff to carry out this work through a series of workshops and feedback sessions. The output will be managed through monthly meetings and progress reports.** **The likelihood of success is considered to be very high**
Project progress **[Year to End of March 2013]**	**A number of meetings have taken place with suppliers, utilities and R&D organisations in China, Japan and Korea, to assess the P&C technology strategy in the Far East, where implementation and integration of digital substation technology is more advanced than the UK.** **The support contract with University of Manchester has been placed and a number of P&C Strategy workshops set up with end users and suppliers.** **The P&C Strategy Document structure and scope and initial drivers has been established and links with other secondary systems initiatives, investment plans and other R&D projects in this area, identified.** **The P&C strategy development is also being closely linked with the Low Cost Country Sourcing (LCCS) Global Procurement initiative.** **The work has proceeded slowly over the past year due to resource constraints and changes to key personnel and availability for workshops.** **The initial workshops were postponed as it became clear that the objectives and their focus needed to be re-scoped, so the project could be better aligned output measure requirements of RIIO.** **An outline set of areas for the P&C workshops has been established and the prioritised areas to be considered for the P&C Strategy has been produced.**
Collaborative partners	
R&D provider	**University of Manchester**

Project title	2050 Energy Infrastructure Outlook		
Project Engineer	David Fidler		
Description of project	This Project will deliver data for the UK on different types of fixed energy infrastructure from now until 2050. The cost and performance data will enable evaluation of different energy scenarios as well as allow for the option of undertaking optimisation analysis. The Project will gather cost and performance data on different types of infrastructure associated with specific energy vectors. The energy vectors under consideration are: • Electricity • Gas • Hydrogen • Heat The degree to which the above parameters can change due to the impact of certain variations will also be captured by this project. The variations in question are: Time – this will provide the variation in the above parameters every 5 years from 2010 – 2050, i.e. 2010 (historic), 2015, 2020, 2025, 2030, 2035, 2040, 2045 and 2050. All cost data will be in real terms relative to 2010. Distance or scale – will provide a measure of the variation in the parameters as a result of distance or scale. A variation in terms of distance is relevant only for transmission and distribution infrastructure, whilst a variation in terms of scale is only relevant for storage. If appropriate, scaling factors are sufficient to represent these variations. Variations to conversions and connections are excluded from this. Overall volume of deployment – the variation in the parameters in relation to the level of overall deployment of the infrastructure, e.g. the variation in cost through economies of scale. UK region – how the parameters would vary within different parts of the UK. Twelve onshore regions are specified (East, East Midlands, London, North East, North West, Northern Ireland, Scotland, South East, South West, Wales, West Midlands and Yorkshire & Humber) as well as nine offshore regions for transmission (Channel Islands, Dogger Bank, East Scotland, Hebrides, Irish Sea, Lundy, Norfolk, Pentland, Shetlands) and two regions for offshore storage (North Sea and Humber).		
Expenditure for financial year 12/13	Internal £9k External £0k Total £9k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£c.100k	Projected 2013/14 costs	£9k
Technological area and/or issue addressed by project	Develop a data set for future project use that will be consistent with DECC, the Energy Technology Institute (ETI) and other ETI members (E.ON, EDF, BP, Shell, DECC, Defra, etc) Outlook scenarios that provide an overview of timescales of infrastructure deployment – this would indicate the costs and timing of alternative infrastructure to gas networks and inform the business to the realistic long-term transition required to switch from gas heating to other networked heating solutions.		

Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		5	-3	8
Expected benefits of project	This project will lead to an improved knowledge of other network infrastructure – hydrogen, District Heat, electric -, increase the understanding of infrastructure deployment capabilities and overall cost constraints It will work towards the determination of policy changes needed to transition / identify which milestones are indicative of strategic change,			
Expected timescale of project	5 years	Duration of benefit once achieved	Ongoing	
Probability of success	40%	Project NPV = (PV benefits – PV costs) x probability of success	-23,226	
Potential for achieving expected benefits	There is a medium-low likelihood of success of achieving expected benefits due to the fact that commercially sensitive information would be required to realise the expected benefit of the project. However due to licence conditions, information in the public domain has had to be used reducing the expected benefits.			
Project progress [Year to End of March 2013]	Four reports have been issued throughout the year outlining the progress of the project, the last one being titled "IWP4 Final Submission" March 2013, the report was submitted in full but there has been some difficulty in obtaining data on Hydrogen networks which is still outstanding from the original scope. The tool for calculating the cost of networks has been created but not validated. The approach is a simplified version of the network which has some regionally variations in costs but does not take into considerations for MVARS or the equipment required to operate the Electricity system as this requires complex system modelling. National Grid will continue to work with BuroHappold and the ETI to check and validate the tool through a series of tests yet to be determined in the upcoming year.			



Collaborative partners	**National Grid Electricity Transmission, National Grid Gas Transmission**
R&D provider	**ETI, Buro Happold, University of Cambridge and Cryil Sweett.**

Project title	Nanocomposite Electrical Insulation Material Development		
Project Engineer	Greg Tzemis		
Description of project	This applied research project addresses the need to achieve systematic processing and production of nanocomposite electrical insulation materials for the reliable manufacture of high performance next generation high voltage direct current (HVDC) power transmission equipment. Major enhancements in performance and properties of key components in new HVDC electrical insulation systems are essential for long-term growth of on-shore and off-shore HVDC systems in the UK and Europe which rely on point-to-point and multi-terminal schemes. This project is highly innovative because it addresses the production of nanocomposite electrical insulation materials and components by establishing property and process design rules for reliable production and processing that are scalable and demonstrates this by the manufacture and realistic testing of a high voltage resin bushing.		
Expenditure for financial year 11/12	Internal £8k External £37k Total £44k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£100k	Projected 2013/14 costs	£32k
Technological area and/or issue addressed by project	The planned Applied Research addresses critical prototyping and scale-up issues for advanced electrical insulation technology, which will support deployment of the next generation of high-efficiency and reliable HVDC point-to-point and multi-terminal transmissions systems from large offshore wind farms to load centres as well as much needed network reinforcement. In these application areas, the operational voltage stresses are extreme and difficult to control so the establishment of higher performance and more reliable insulation material solutions, yet still remaining affordable is one of the major challenges that the electricity transmission and distribution industry faces today. Nanodielectrics have already demonstrated clear potential to address these areas, but the lack of systematic processing studies has resulted in poor control to attain these superior properties in a reliable and reproducible way. Successful insulation technology demonstration and its subsequent implementation is therefore seen as vital to supporting timely expansion of renewable generation and its integration in the UK power grid, i.e. allowing 2020 UK CO_2 emission targets to be met, whilst reducing energy costs and increasing security of supply. In the longer term, the advanced materials will be used as critical components in the European Supergrid, which will allow deep penetration of renewable generation across the whole of Europe and enable the full potential of the UK's offshore wind resource to be exploited. The same technology is also transferable to all large global power markets. In laboratory R&D, nanocomposite electrical insulation materials have been shown to significantly out-perform conventional micro-composite insulating materials in both HVAC and HVDC application conditions for the reasons cited above, but transfer to engineering practice has been problematic. It is essential to advance our state-of-the-art knowledge and technology to		

	support prototyping and subsequent fullscale demonstration. The planned work includes mastering the different facets of nanophase processing of cost-effective materials for repeatable and scale-independent manufacturing of preproduction materials for optioneering and optimisation as well as for demonstrator HVDC components that test scalability. The development will use state-of-the-art processing and measurement methods to establish design and processing rules and to support the design of components with highly optimised electrical and physical properties that can withstand the multistress environments found in HVDC systems.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		7	-5	12
Expected benefits of project	The project addresses two synergistic business opportunities: a) the rapidly developing global market for next generation HVDC technology, and b) smaller footprint/lower cost power equipment. HVDC technology is in a period of rapid change with development of Voltage Source Converters (VSC). This is disruptive, allowing deep penetration of renewable energy sources, establishment of multi-terminal HVDC and creation of SuperGrids. Substantial investment has been made in developing VSC converter systems. These use electrical insulation developed for classical HVDC, impacting system size, mass, cost and market acceptance. The availability of higher performance electrical insulation materials will meet advanced HVDC needs and provide opportunities to trade-off size and cost. Innovative, nanocomposite based electrical insulation materials appear to provide the performance required. This project focuses on the work necessary to produce demonstrator components with these materials and test them under arduous conditions, thus driving rapid exploitation. If successful the project will contribute savings and efficiencies in the future HVDC developments (estimated potentially as small % of total costs). The project is supported by Alstom (they are developing a £1m project based on the success of this project), the Technology Strategy Board (48% funding of project costs), Mekusa (£15k as a supplier) and SSE and Scottish Power (circa £100k each of IFI funding).			
Expected timescale of project	3	Duration of benefit once achieved	8	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	8517	
Potential for achieving expected benefits	As a shared collaborative TSB supported project, the likelihood of application to the network is uncertain at this time however the level of funding has good leverage and important lessons will be learnt and applied to further work and a potential commercial product. The immediate benefits will be improved knowledge for application to National Grid policies.			
Project progress [Year to End of	The Project is underway with good momentum and attentive project management. Progress meetings have been held quarterly. National Grid			

March 2013]	**successfully hosted a Meeting in September 2012.** **The project is meeting its objectives and the focus is moving from choices of the materials to more investigative work within the partners.**
Collaborative partners	**Scottish Power, SSE**
R&D provider	**Alstom, Gnosys, Mekufa**

Project title	**Co-managed Innovation Projects (SSE/NG/UMIP)**		
Project Engineer	**Mark Osborne & Tony Westmorland**		
Description of project	**The CMEIF is a fund agreed jointly between National Grid (NG), Scottish and Southern Electricity (SSE), the University, University of Manchester Intellectual Property (UMIP), and the UMIP Premier Fund (UPF). The nominal value of the CMEIF is £1M comprised of funds set aside by each partner as follows:** • **National Grid - £300,000** • **SSE - £300,000** • **The University - £200,000** • **UPF - £200,000** **The fund was established to stimulate and develop novel innovations and technology arising from the University for utilisation in the electricity generation and distribution industry..**		
Expenditure for financial year 12/13	**Internal £5k** **External £81k** **Total £86k**	**Expenditure in previous (IFI) financial years**	**Internal £0k** **External £0k** **Total £0k**
Total project costs (collaborative + external + [company])	**£1m**	**Projected 2013/14 costs**	**£85k**
Technological area and/or issue addressed by project	**The Co-Managed Energy Innovation Fund has been created to identify and develop novel research and technologies for commercialisation and utilisation by the distribution and transmission industry to improve delivery of electricity to customers.** **The Co-Managed Energy Innovation Fund is looking to provide funding, typically up to £100,000, enabling University researchers to undertake one-year projects on innovations to demonstrate proof-of-principle.** **The first invention describes a novel Dual-VOAS Based Optical AC Current Sensor for use in an Optical Current Transformer (OCT). The novelty lies in the design of an electro-optic amplitude modulator, whose modulation depth is in a fixed relationship with the driving voltage. The sensor uses a Rogowski coil to produce a voltage which then modulates into optical signal by two MEMS (Mechanical Electrical Micro System) based VOAs (Voltage optical attenuator). The modulated optical signals are transmitted via fibres and then detected and amplified by the optical transceiver device into an analogue signal that is proportional to the high voltage conductor current. The commercial challenging issue that this invention solves is the use of Rogowski coil and Op-Amps for stability combined with the capability to operate without a battery bias circuit.** **Wide-Area Monitoring, Protection and Control (WAMPAC) applications have become an important tool for engineers to analyse the behaviour of large modern power systems. Synchronised Measurement Technology (SMT) consisting of Phasor Measurement Units (PMUs), communication media and protocols, and Data Concentrators (DCs) allows the engineers to have information of voltage and current phasors and frequency information, synchronised with high precision to a**		

common time reference provided by the global positioning system (GPS). SMT has already been used to locate faults, estimation the state of the network and monitor voltage, frequency and angular stability, and numerous other aspects of the network. It is expected that in the future WAMPAC systems will include Intentional Controlled Islanding (ICI) [1] and Power System Restoration (PSR) [2] applications designed to reduce the number of catastrophic black outs and generally improve the reliability and security of energy production, transmission, and distribution, particularly in power networks with a high level of operational uncertainties. At present the applications needed to justify and fully utilize the power of WAMPAC systems simply do not exist.

An application that is able to help with ICI is highly desirable as it splitting the system into smaller subsystems, or islands, would help avoid system wide instabilities, cascading outages and black outs. The University of Manchester has developed an application that is capable of splitting the power system into a number of islands after a large disturbance. The method works by determining the weak areas in the power system and splitting the network across the transmission lines with the lowest power exchanged, strong connected islands are created, the power oscillations between areas are reduced, and better load-generation balance is obtained. The weak areas are the links where application is most likely to split the network. Since the stability margin in the created islands is lower than that of the entire power system, the created islands may reach the black out, even after the control actions are intensively carried out. It is more economical to experience a black out of a small island, than a black out of an entire power system. Therefore, in order to restore the operation of a single island, blackstart availability and sufficient generation capability within each created island are included in the proposed methodology. These new constraints can be viewed as a power system restoration planning stage. The method has been successfully tested using two IEEE test networks but further testing of this application is required. This means that the proposed islanding application should be tested by using the GB network, which as such is much more complex than the mentioned IEEE test networks.

An application that is able to help with PSR after a partial or complete black out is highly desirable. The objective of a PSR application would be to restore the power system, using a particular restoration strategy, as quickly as possible within all the constraints previously defined by grid codes. Due to the increasing demand and the introduction of economic competition, modern power systems operate closer to their stability limits, increasing the probability of partial or complete black outs increasing the need for a PSR application [3].

Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		9	-2	11

Expected benefits of project

Projects supported by the fund will be focused on market areas defined by National Grid and SSE, be innovative and enable development and/or creation of commercially valuable IP, will typically cost up to £100,000 and have duration of no more than 12 months.

Dual-VOAS Based Optical AC Current Sensor,

- Uses modulation rather than the common Faraday Rotation effect.
- Does not need a power supply. Powered by Rogowski Coil.
- More stable. Is not affected by vibrations caused by weather.
- Reduced production cost as need for large OCT (to compensate instability) is not an issue.
- Does not need the light source to be exact and fibre length fixed.
- Potential to utilise digital automation.
- Can be used with the IEC-61850 protocol, meaning one CT can be used where several were required before. (IEC 61850 is a standard for the design of electrical substation automation).
- Potential to be used across a range of relay types.

Wide-Area Monitoring, Protection and Control (WAMPAC). There are a number of benefits associated with the PSR and ICI applications making the applications very attractive to TNOs and DNOs.

Financial savings: Preventing blackouts and speeding up system restoration will result in significant savings.
Risk management: Network performance would be improved with a robust islanding solution, or fast and reliable restoration strategy. The risk of total blackouts will be reduced and the risk of new blackouts during system restoration will also be reduced.
Safety: Preventing blackouts combined with PSR and ICI applications for when blackouts do occur will enable the PSR procedure to be simpler, faster and more reliable, leading to a new stable and normal system state more quickly which would reduce safety concerns.
Other benefits: There are also benefits for society as a whole as these applications will minimize the cost of customers' outages and time necessary for system restoration, enhance protection and control of power system, reduced impacts of potential system attacks and reduce CO_2 emissions and environmental impact of system operation.

Expected timescale of project	**Multiples of 12 months**	**Duration of benefit once achieved**	**Ongoing**
Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**68805**
Potential for achieving expected benefits	**Risks are shared with SSE and the University of Manchester and the project is being managed by the University of Manchester's Intellectual Property team in order to achieve delivery.**		
Project progress **[Year to End of March 2013]**	**The projects started in February 2013 and should be finished within one year. Two post doctoral research assistants have already started work, the third one is about to join the team in September 2013. The key project deliverables; Intelligent Controlled Power System Islanding and Power System Restoration will be filed as patents. The first patent application (Islanding) is about to be completed. Development of testing the applications using Alstom-Grid testing facilities is under preparation. Work is about to start on the second patent application (restoration).**		
Collaborative partners	**Alstom Grid, SSE**		
R&D provider	**University of Manchester**		

Project Title	PPE - Closing the loop for Commodities and Workwear		
Project Engineer	Chris Plester		
Description of project	This project will deliver a pilot programme to assess the opportunities for National Grid to close the loop on specific asset types, especially high volume commodity items such as site signage and demarcation and work wear. The approach is potentially applicable to a range of asset types but this pilot will focus on the high volumes of personal protective equipment (PPE) and workwear to establish the principles and develop the underlying processes before considering other asset types. The pilot will deliver a well researched programme to enable National Grid to become the first zero waste, and then in a phased approach, closed loop user of work wear and PPE, through a partnership approach built between our suppliers, National Grid and pioneers in this area, Worn Again. This pilot project will deliver 1. Proposed recycling/disposal route(s) for PPE textile garments. 2. Cost/benefit analysis for a collection system and recycling/disposal route. 3. Collection pilot system developed, budgeted and tested. 4. Employee engagement/awareness sessions and external communication. 5. Up-cycling option identified and proposed. Highlight opportunities to extend to other commodity lines.		
Expenditure for financial year	Internal £5k External £25k Total £30k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£30k	Projected 2013/14 costs for National Grid	£0K
Technological area and/or issue addressed by project	Closed loop approaches aim to build cycles of use and re-use for assets and materials, maintaining the value of the materials and eliminating waste. It is a route to drive efficiency in cost and resource use and minimise environmental impacts through elimination of waste. Worn Again are pioneers in the field of textile recycling, up-cycling and embedding closed loop approaches in uniform workwear. They have led projects including the up-cycling of Eurostar and Post Office uniforms into bags and other equipment and have successfully driven zero waste practices into the handling of end-of-life garments. Working with MacDonalds they will introduce the world's first closed loop uniform items from mid-2012. These approaches drive significant efficiency in supply and disposal of uniform garments and have driven considerable publicity and reputational gain for partner organisations. National Grid spends significant sums on work wear and PPE. From April 2010 to March 2011, over 155,000 items were issued to staff at a cost of £2.64m. This included the issue of 55,500 items classed at PPE garments at a cost of £1.4m. There is currently little control of the issue of new PPE and work wear and no process to manage either the return of excess items or		

	disposal at end-of-life. At the present time there is no mechanism in place at sites to collect and dispose of unwanted/damaged PPE. In the absence of any data, the assumption has been made that these are being disposed individually through home recycling facilities. Although disposal routes have little control some will be recovered from general waste streams at materials recovery centres and typically shredded and used as post-consumer materials such as stuffing for car seats. This occurs at cost to National Grid and with no control over what is or is not landfilled. Through embedding new partnerships it is possible to sharpen this process and drive benefit. A programme to collect and accumulate excess and end-of-life workwear for processing either as reissue, processing into zero waste materials for other processes (including car seat stuffing) or up-cycling into new consumer products and eventually processing for remanufacture will eliminate waste and reduce requirements for new, virgin materials for workwear manufacture. It will drive tangible benefits in direct cost reduction and indirect cost reduction in (hidden) disposal costs, help to engage staff in more sustainable practices and drive environmental gain.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score
		9	-1	10
Expected benefits of project	Building programmes to manage resources effectively including commodity items such as workwear and PPE will help to engage staff in more efficient ordering and use of these items. Embedding an effective process for eliminating waste and subsequently closing the loop on these items will also drive considerable reputation benefit especially if National Grid takes this opportunity to take the lead. Benefits will accrue through: 1. Order management process to encourage the return of an item when it's replaced. 2. A focused manageable system in place to reduce and subsequently eliminate disposal to landfill. 3. A series of awareness programs to highlight the benefits to the business as well as the individual. 4. An opportunity to up-cycle clothing into promotional items which will have a cost reduction benefit. Drive a focus on the issuing process with an achievable target of 10% order reduction which alone will save approximately £140,000.			
Expected timescale of project	1 Year	Duration of benefit once achieved	8 years	
Probability of success	80%	Project NPV = (PV benefits – PV costs) x probability of success	£47,200	

Potential for achieving expected benefits	**The first stage of this project will identify the options from simple collection, recycling and waste elimination process. The range and volumes of items issued and used has been communicated to Worn again and they have high confidence that efficient approaches can be embedded in our business. The likelihood of success is very high. Further stages building options of up-cyling and embedding closed loop approaches have a high likelihood of success given the nature of most materials involved in workwear and PPE used in transmission activities. Detailed discussion of processing of high value NOMEX fibres will be undertaken with the manufacturers.**
Project progress **[Year to End of March 2013]**	**The feasibility study carried out by Worn Again identified that the opportunity to up cycle and close the loop on PPE and work wear within National Grid was relatively small. The majority of 'waste' items were unsuitable for reuse or remaking due to their properties and specifications.** **However, the study identified significant areas within the procurement and returns process that could be improved and as a result National Grid is working with their suppliers, Greenhams, to address these issues.** **Safety, Sustainability and Resilience (SSR) and Global Procurement have been working to identify potential recipients for PPE waste products and are working with incumbent waste resource providers to investigate wider solutions for textiles and PPE. Within 2013-14 small scale trials will be facilitated across the business.**
Collaborative partners	
R&D provider	**Worn Again**

Project title	EPRI Substations		
Project Engineer	Jenny Cooper		
Description of project	This project encompasses National Grid Electricity Transmission's participation in selected Power Delivery projects from the EPRI (Electric Power Research Institute) R&D Programme. Projects are selected to enable maximum beneficial project interaction and maximum leverage on funds. Additional technical collaborations and access to existing products are included as part of the agreed collaboration at no additional cost together with access to the Technology Innovation Program and participation in the Research Advisory Council.		
Expenditure for financial year	Internal £13k External £402k Total £415k	Expenditure in previous (IFI) financial years	Total >£2m
Total project costs (collaborative + external + internal)	> £100m	Projected 2013/14 costs for National Grid	£383k
Technological area and/or issue addressed by project	Project areas: • Greenhouse Gas Reductions Options • Conductor and Wire Corrosion Management • Foundation Analysis and Design • Improve Transmission Line Lightning Performance • Polymer and Composite Overhead Transmission Line Components • Impact of High-Temperature Operation on Conductor Systems • Transformer End-of-Life & Condition Assessment • Transformer Life Extension • Circuit breaker condition assessment and life extension • Using relays for circuit breaker diagnostics • Fault current management • Protection and control • Advanced Conductors • Assessment & Evaluation of Next Generation HVDC Technologies • Life Extension and Best Practices Guidelines for Substation Equipment • Improving Overall Substation Maintenance Management • SF6 Environmental Management and Equipment Performance • Solid-State Fault Current Limiter/Circuit Breaker Development • Management of Substation Ground • Ground Grid Evaluation, Maintenance Refurbishment • Energy Storage (Transmission) • AC/DC Line Conversion • Antenna arrays and wireless mesh sensors for partial discharge location • Zed meter trial • Technology and Innovation Programme including sustainability		

Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score
		11	-2	13

Expected benefits of project

EPRI is probably the largest research organisation in the world with a large-scale interest in the electricity Transmission business. The organisation is keen to implement research programmes between suppliers and utilities, thus encouraging innovation and bringing novel ideas closer to the market. National Grid is an invited member of the Research Advisory Group – the executive level group steering the complete research programme.

The key benefits to National Grid of being involved with EPRI include:

- Gain access to a wide range of R&D objectives both underway and planned.
- Participate in multi-user discussion and networking including setting the direction of applicable EPRI projects.
- Commercialisation of R&D into products that can be purchased with minimum risk due to knowledge gained in R&D.
- Trials comparing diagnostic tools – benefit gained from collaboration as National Grid would not support this activity individually.
- Evaluation of benefit from application of techniques/software currently in development through EPRI projects.
- Establish further opportunities for tailored collaboration for demonstrations and trials with further shared risk and cost sharing.
- Access to experts with complimentary skills to in-house specialists.
- Access to existing products (value up to 10% of contracted costs) – both reports and intellectual property/applicable knowledge.
- To influence the direction of the EPRI programme to National Grid's best interests through participation in EPRI project working groups and advisory councils.
- Significant leverage on funds estimated to be 50:1 in substations.
- Access to EPRI information is open to all National Grid Transmission employees with a password enabling access to the specifically funded projects and the technology innovation projects.
- The National Grid selection from the EPRI programme delivers applied research with defined benefit to National Grid's assets including improved transformer analysis, SF_6 leakage recommendations and substation monitoring via antenna array technology based at the University of Strathclyde.

- **The total project portfolio for EPRI in the transmission research area is over $100million per annum, National Grid's selection forms part of this total activity giving significant leverage and potential for developing multi utility collaboration on projects leading to networking, cost and risk sharing.**

Specific benefit areas:
Transformers: National Grid has a major transformer replacement programme; understanding the end-of -life processes, condition assessment methods and any possibilities for life extension is required to optimise this expenditure. The EPRI projects provide an international perspective to this activity to supplement the other work, both past and ongoing, that is saving something in the region of £5M per year in capex in terms of avoided replacement and failures if the replacement decision making process was less well informed. Additional incremental benefit from ongoing research is difficult to quantify precisely, but failure to be informed and up to date in a critical asset management area would have a damaging effect on both revenue and reputation. The EPRI work contributes at least 1% of the £5m per annum and is applied via National Grid's transformer specialist.

Circuit breakers: The EPRI project provides an international perspective of risk based asset management, condition assessment methods, guidance on material selection and application, maintenance task and timing and any possibilities for life extension required to optimize expenditure. Benefits come from being able to develop rationale necessary for ongoing and future maintenance and asset management policies and staying abreast of industry maintenance and asset management practices.

SF_6: Strong environmental driver to be involved. Good successes in previous years with benefit achieved through the development of leak sealing technology and partial discharge trials, both leading to implementation on the system.

Earthing: The benefits of collaboration on the earthing (grounding) project will allow for alternative methods of test to be examined and validated, resulting in a potential cost saving to National Grid Transmission through efficient incorporation of the techniques into National Grid's operation.

Overhead Lines: Application of TFlash lightning modelling software to analyse performance of current and future assets, also added potential to assess impulse tower footing resistance. Complimentary work to ensure knowledge of asset management of composites in terms of lifetime, handling etc. Facilitating reduced operations and maintenance costs while supporting an aging infrastructure with reduced capital expenditure for new and refurbished equipment. Need to improve reliability and worker safety.

Substations: Safety of people and equipment during

	operations and outages. Enhancing system reliability, performance, and life of equipment on ever-decreasing maintenance budgets has become essential for an infrastructure that has reached its design life of 40 years. Advanced technologies and tools are needed to maintain and operate substation equipment in the increasingly competitive energy marketplace Transmission System Development: Safeguard, protect, and modernize transmission grids. Increasing transmission capacity utilisation is necessary to ensure grid stability. Need to eliminate or relieve transmission bottlenecks to the market reach of competitive generation. Need to increase the robustness of the transmission grid through use of tools that enhance both steady and dynamic state Performance Sustainability: Understanding implication for National Grid – Model for building sustainability in terms of inputs, operation and delivery of energy. Combined utility view of benefits of sustainability in terms of reduced impact on asset management leading to environmental and cost benefit to the customer.		
Expected timescale of project	5+ Years	Duration of benefit once achieved	10+ Years
Probability of success	50%	Project NPV = (PV benefits – PV costs) x probability of success	£210k
Potential for achieving expected benefits	EPRI feedback from combined utility membership indicates that with a leverage of up to 50:1, there is potential for achieving benefits through • Maintenance guidelines can extend equipment life by 5–10 years. • Condition-based maintenance reduces maintenance costs by up to 30%. • SF_6 management can reduce losses by up to 50%. • Predictive maintenance will reduce maintenance costs by up to 10%. • Preventing failure of critical transformers will save £2–5 million per unit. • New overhead line design tools that can reduce capital expenditures by up to 5%. • Accurate overhead line component condition assessment will be improved to accurately diagnose incipient fault conditions, increasing transmission reliability. • Increased knowledge and understanding of technology-based methods to alleviate transmission capacity constraints and help them optimize use of existing transmission assets. • Extending the market reach of competitive generation by eliminating or relieving transmission		

bottlenecks.

- **Enhanced experience and knowledge about which technologies will increase the robustness and integrity of transmission grids by avoiding or minimizing the impact of cascading failures, voltage collapse, and other major disturbances.**

Membership of the EPRI Lightning &Grounding Task Force has delivered National Grid guides on the different types of overhead line (OHL) earthing and how to apply them, as well as guidance on the different types of test methods and when to use them. The Task Force is also in the process of delivering a specification for a test meter to allow the earth impedance of individual towers to be measured without removing the earthwire at the peak. This Task Force is also responsible for the development and maintenance of the TFlash software which is used to manage the risks associated with lightning and OHLs, specifically the software allows the probability of an OHL being struck by lightning to be calculated and the potential consequences to be evaluated.

Application of the Antenna Array trials have reduced radio frequency interference surveys – removing need for weekly surveys and hence saving manpower directly (estimated as 100 hours minimum per survey). Potential failures avoided this year have been a current transformer and a supergrid transformer due to bushing failure on a supply to a major consumer. The avoided costs from these failures are considerable amounting to an estimated £5m but also avoided potential disruption to customers. The Scope of the project has been increased due to the large variety of partners in the project which has identified additional benefits to the system. Pollution has successfully been monitored and also small cracks in insulations. The project is now looking to find the limitations of the device, the best way of dealing with Noise and how the data can be realistic cleansed. There have been proactive replacements of equipment from partners in this project already in the trial stages cementing the potential benefit this project could have on the network.

Work to develop a technique of testing ceramic insulators for defects with the circuit energised has developed to the proof of concept stage. Successful testing at Eakring test facilities has identified the possible best technique which now needs further development.

Sunburst – Work is currently ongoing to update the hardware from the late 90's to enable the system to be used in line with strategic asset management (SAM) and EPRI forecasting studies are to be incorporated into the system.

SF_6 – Alternatives to SF_6 are still being investigated at the moment. There has been a sharing of best practice for leak repair techniques which has been incorporated into SAM.

Using relays for circuit breaker diagnostics – There has been a sharing of utility practices to better understand how data in relays is being used for circuit breaker diagnostics

	and techniques to incorporate this data into SAM using standards based approaches. In coming years, there will be more opportunities to field try EPRI research findings and apply results. **Circuit breaker condition assessment and life extension – Application of ongoing EPRI research results enables utilities in improving their maintenance procedures and specification and procurement practices. Specifically for National Grid the progress achieved so far has enable National Grid to define the rationale to standardize products – for example, circuit breaker greases. Prior to engaging in this work National Grid had over 85 products in use for circuit breakers all over the system. Furthermore, the information exchange through a 7 day session with EPRI collaborative utilities in a workshop environment assist in creating further awareness especially in prevalent maintenance practices.**
Project progress as of end of March 2013	**Previous deliverables are recorded in previous annual reports, those achievements delivered and in progress in EPRI Technology Programme are:** **Conductor, Shield Wire and Hardware Corrosion Management - This project identifies, develops, and assesses tools and procedures required to deal with conductors, shield wires, and hardware exposed to atmospheric corrosion. Near Infrared Spectroscopy has been developed as a non contact screening tool to quickly flag conductors that have experienced steel core degradation. The hope of future research is to refine that technology into a predictive tool so that it will discriminate between levels of degradation. Time to complete an inspection is minimized so cycle times may be reduced and crew sizes are reduced to a minimum with the elimination of heavy equipment and support logistics.** **Compression Connector Management - This project provides a holistic approach to the inspection and management of compression connectors. Recommendations were derived on the use of Infrared (IR) cameras for the inspection of compression connectors. Compression connector failure data was analyzed and reported. A new method of inspecting compression connectors for defects was evaluated and found to be not as effective as the existing methods of evaluation. Better IR measurements can be made of compression connectors and conductors. Trends in compression connector failures have been identified. More accurate compression connector inspection technologies can be used by utilities.** **Lightning Performance and Grounding of Transmission Lines - This project is a mix of tools, training, and information that will help members improve their transmission line lightning performance.** • **Effect of Seasonal Variations on Transmission Line Grounding measurements: This information based on field data provides field engineers information on the effect of seasons when making ground measurements.**

- **Grounding Practices for Structures Close to Substations: This provides design engineers with issues related to various design options and their impact.**
- **Compare Lightning Location Networks with utility fault data: This task compares information provided by vendors with known lightning caused outages to determine accuracy.**
- **Lightning & Grounding reference book: The reference book is a self-contained, state-of-the-art resource on lightning and grounding and their effects on transmission line performance.**

Improved lightning performance and safety of transmission lines by providing engineers with effective tools and an improved knowledge base.

Overhead Line Design and Research - This project develops comprehensive design guidelines to assist designers in evaluating, selecting, and designing cost-effective structures suitable for overhead lines. A practical reliability-based design approach is to be developed. Interaction among other components, such as the foundation, will be considered. The project will also provide information on electrical clearance requirements for structures. Knowledge gaps will be addressed. A foundation design manual covering the state-of-the-art information and design methods was prepared. The foundation design manual provides comprehensive information to engineers in evaluating, selecting, and designing foundations suitable for single pole, H-frame, lattice tower, and guyed-V structures.

Live Working: Research, Techniques and Procedures - This project develops tools, procedures, and training materials for live and de-energized work to enhance worker and public safety, work efficiency, and reduction in cost and duration of maintenance outages. In 2013, the topics include:

- **New jacketed live working rope. A sample of about 200 m was received for tests. Test will be performed per IEC 62192 and ASTM F1701. Also, because the rope cannot be spliced or tied in a knot, endfittings will be developed and the integrity of the jacked-endfitting seal will be tested to ensure that it can prevent moisture ingress.**
- **Determination of "critical defects" in polymer insulators. Users of the new polymer insulator tester need to know the "worst" defect that still does not degrade the integrity of the worksite. Switching impulse tests will be performed in full-scale mockups of structures, with tools and workers represented by mannequins, to characterize "critical defects".**
- **Training materials for live work on high-temperature conductors. Effects of high temperature on live working tools, and effect of tools (clamps) on soft (annealed) conductor strands have been investigated over the past few years. Findings will be summarized and training materials developed.**
- **Edition 4 of the EPRI Live Working Reference Book will be published in 2013.**

- Guidelines for safe opening of jumper loops. It is often necessary to remove jumpers of energized lines to isolate segments for maintenance. While the line load can be dropped, it is not always possible to eliminate the line capacitive charging current. This capacitive charging current must be interrupted manually by removing jumper cables on structure. Guidelines for maximum segment length that can be isolated in this manner will be prepared.
- Live working friendly structures. There are certain features and requirements for design and construction of overhead lines that help facilitate live work, while absence of these features can hinder live work. It is more effective and less costly to incorporate these features at the line design stage that to retrofit completed lines. A report will summarize these features and lessons learned.

Over the past quarter-century, the EPRI live working project has helped utilities reduce maintenance costs and improve worker safety through research into live working. Notable results include development of Minimum Approach Distances for helicopter-based work, development of the Portable Protective Air Gap as a tool that provides positive control of worksite overvoltages, assessment of ropes for use in the energized environment, development of guidelines for live work on compact lines, science-based validation of Minimum Approach Distances, assessment of robotics for live work, etc.

Polymer and Composite Overhead Transmission Line Components - This project addresses the use and maintenance of composite transmission line components. Through this project, members learn how to select, install, inspect, and maintain composite transmission line components used throughout the world.

- E-field modeling software that will help in selecting the correct size grading ring.
- Population assessment software to assist in prioritizing inspections.
- Assessment of long term performance of polymer components through various aging chambers.
- An understanding of the degradation mechanisms of insulators and how to mitigate them.

This project provides an understanding of how the components design and operating environment impact the long term performance of polymer components and identify installation methods that can mitigate the degradation and achieve maximum life. Members also are alerted to industry issues related to polymer components that may require additional inspections.

Performance and Maintenance of High-Temperature Conductors - This project conducts research to address issues related to high-temperature conductors. It investigates the long-term performance of all commercially available advanced conductors to complement the field demonstration project, which provided information on handling and stringing of these conductors. Maintenance

tools and procedures for this new type of conductor will also be identified and established. A comprehensive guide for the selection and application of high-temperature conductors will be prepared. A test procedure with proper evaluation criteria has been developed to qualify carbon fibre core advanced conductors. Maintenance issues for high-temperature conductors were identified and are being addressed. The project provides an effective tool to evaluate various carbon fibre core conductors for purchases and bring awareness to the members on issues related to maintenance of high-temperature conductors.

Transformer Life Management - Effective transformer life management via novel condition-monitoring techniques and new algorithms for turning that condition-monitoring data into actions. New technologies for better transformer life estimation. Novel membrane techniques for transformer life extension. Knowledge retention and transfer through a comprehensive guidebook and collaborative sharing of forensic results.

- **Application Guide for Advanced Condition Monitoring: The guide assists in specification, application and interpretation of advanced condition monitoring tools for transformers. Application of the results is obtained through using the guide and participating in the laboratory and field trials.**
- **EPRI Transformer Guidebook Development: The Copper Book. This valuable guidebook provides guidance from a utility engineer's perspective on all aspects of a transformer's life-cycle. It combines all EPRI's transformer research into a practical guide. The application of the results is through use of the guide at each decision point and through learning at Copper Book training courses.**
- **Forensics Library for Transformers: The computer-based library allows rapid access to detailed lessons from transformers taken out of service prior to failure. The application of the results is through the use of these case studies as a decision support tool for monitor, repair or replacement decisions.**
- **Root cause and failure investigation guide: This guide walks the reader through the key steps and checklists needed for a failure investigation. The application of the results is through the use of this guide in preparation for an investigation and then throughout the actual process.**
- **Membrane technologies for lifelong oil filtration: The research has successfully developed a prototype unit that is staged for a 6-month field trial on a full-scale transformer in the EPRI Lenox laboratories. The immediate application of the results is participation in field trials. The final application is use of a readily available and affordable filter through licensing of the research.**
- **Improved transformer aging estimations using new chemical markers: A chemical marker ratio has been successfully identified as a likely candidate for more accurate paper life estimations. The immediate**

application of the results is through testing the new approach in your own transformers through provision of samples. The final application will be the proven guidance on improved transformer decision-making on end-of-life.

- Novel sensors for transformer diagnosis: A new approach to Hydrogen and Acetylene detection has been developed and prototyped using Photothermal lensing. The immediate application of the results is through participation in field trials. The final application is use of a readily available and affordable sensor through licensing of the research.

The research results are structured to help anticipate and prevent transformer failures, extend transformer life. The research develops knowledge and tools to improve inspection, condition assessment, and risk-based asset management. Finally – the research develops novel sensing technologies that allow for deeper insights into the present condition of these critical assets.

SF_6 Management - This project helps members address SF_6 issues through improved safety, reduced SF_6 emissions, and enhanced knowledge capture and training. The project specifically addresses improving handling of SF_6 losses and tracking of SF_6 and handling in support of tighter regulation on SF_6 inventories.

Geomagnetic Disturbance (GMD) - The initial objective will be to determine the state of knowledge of GMD. This will include a review of the available literature and interviews of industry experts, to collect and validate industry data on the probability of extreme events and the extent to which storms can reasonably be anticipated. Today numerous technologies and approaches are available with the claim to lessen the impact of solar storms. A centre of expertise will be developed to test and assess mitigation technologies, perform system studies, and answer member questions and concerns. Existing technologies will be tested, such as neutral blockers, and operational strategies. Mitigation will include technologies that can reduce the extent of the impact or reduce the duration of outages. The impact on the protected equipment will be evaluated, along with the possible impact on adjacent lines, transformers and mitigation equipment.

A guidebook covering mitigation and recovery practices will be produced covering present and emerging technologies for forecasting, practices covering early warning, operations, and restoration, as well as mitigation technologies.

HVDC Technology Surveillance and Reference Guidelines - HVDC Reference Book was published with all 24 chapters at the end of 2012. This Reference Book will be further updated with additional chapters such as Life Extension, AC to DC Line Conversion, & Grounding, and some existing chapters such as Voltage Source Converters will be updated as the technology is changing fast.

It is important that the power industry has access to the

latest developments and advances in HVDC technology. EPRI continues to build a comprehensive library of information on HVDC technology for the benefit of the industry. EPRI has been developing reference materials that capture and consolidate related HVDC information and knowledge.

Applications of HVDC Technology and New Developments - This project will address various HVDC applications. One of the applications is connecting renewables to the grid. It also will provide different transmission interconnection options based on technical and economic benefits. Further, it will explore and address issues related to designing and operating dc grids, dc circuit breakers, and dc-to-dc transformers. In the past, the ac-to-dc conversion study under this project clearly showed that increase in power transfers can be obtained in the range of 50 to 100% depending on the voltage level and type of ac structures. EPRI also has investigated asymmetrical HVDC line design and operation in which the negative pole can be operated at higher voltage than the positive pole for the same voltage gradient and electric field constraints, thus increasing total power transfer by 10 to 20%. Presently, the focus of this project has been changed to other HVDC applications such as transmission requirements to connect renewables to the grid and new developments such as dc grids and dc circuit breakers for achieving such applications as well as HVDC cables.

Integrating HVDC in an AC Grid - This project addresses various system impacts when HVDC interconnections are implemented in a meshed ac grid. Overall transmission capacity can be increased by adding HVDC interconnections with a much greater flexibility in controllability and increased reliability. System planning studies will be performed as a first step before considering HVDC interconnections in the existing ac grid to assess the impacts of HVDC. There is a growing need for systematic evaluation of impacts of HVDC on the ac grid using the HVDC models for latest converter technologies such as multi-level VSC converters. This project will address the HVDC impact evaluation studies using benchmark test systems and the necessary model developments.

Impact of HVDC Embedded in An AC Grid - Building on the results from the base funded project on the same topic, this project performs GB specific system studies (load flow and stability) considering HVDC additions to the existing AC grid. The objective is to develop utility specific strategic solutions for the following:

- **Power flow optimization**
- **Power oscillation damping**
- **Wide area control systems**
- **Transmission requirements for wind integration**
- **Special protection & control strategies**
- **Coordination of dc control with other ac network controls including generator**

	controls – Sub-synchronous Resonance (SSR) damping – Transient stability improvements – HVDC Models System studies were conducted using the DIgSILENT Power Factory software on Power flow optimization, Power oscillation damping, and Wide area control systems during 2012. During 2013 work is progressing on Transmission requirements for wind integration, Special protection & control strategies, and Coordination of dc control with other ac network controls including generator controls. In the Great Britain (GB) transmission system the power transfer capacity between Scotland and England (commonly known as 'Anglo-Scottish boundary') is limited by the angle stability constraint. In order to increase the North-South transfer capacity, several upgrades are planned. This includes installation of series compensation and sub-sea HVDC cable links along the west and possibly east coasts of UK. The 2.2 GW Western HVDC link is expected to be commissioned by 2016/17 and would use the traditional line commutated converter (LCC) technology. In addition to offering the additional 2.2 GW capacity, the Western HVDC link may be used to improve the stability of the AC network under high North-South power transfers. Several case studies on a reduced equivalent of the GB transmission system are reported to highlight the role of the planned Western HVDC link in making better utilization of the AC network by improving its stability limits.
Collaborative partners	**World-wide utilities and universities through EPRI collaboration.**
R&D provider	**EPRI**

Project title	FEA modelling of Current Transformers with composite insulators in various rigid Busbar configurations			
Project Engineer	Tony Westmorland			
Description of project	The structural performance of post type current transformers (CTs) fitted with composite supporting rigid tubular busbars cannot be practically demonstrated by direct testing methods alone. Finite Element Analysis (FEA) offers a reliable method of determining the behaviour of materials under various conditions and scenarios that can be envisaged in typical busbar configurations. The data collected from the FEA modelling study is anticipated to lead to the introduction of composite insulators on post type current transformers as a safe alternative to current transformers fitted with ceramic insulation.			
Expenditure for financial year 11/12	Internal £5k External £5k Total £10k	Expenditure in previous (IFI) financial years	Internal £3k External £36k Total £39k	
Total project costs (collaborative + external + [company])	£49k	Projected 2013/14 costs for National Grid	£0k	
Technological area and/or issue addressed by project	The recent catastrophic failures of GEC FMJL post type current transformers represent significant safety hazards to National Grid personnel and third parties. Failures have resulted in complete disintegration of the ceramic insulator and widespread dispersal of porcelain fragments over large areas of the site. Sites affected currently have Risk Managed Hazard Zones (RMHZ) of up to 75 metres around each FMJL unit which is preventing system access to carry out essential capital infrastructure and replacement work. As an alternative to porcelain, composite insulators can be supplied as an option by most of the post type CT manufacturers. These are typically of silicon rubber material which has the advantages of being lightweight, superior in terms of pollution performance and more importantly are inherently safer then porcelain insofar that they will not shatter or fragment. This project will investigate the impact of replacing current transformers with porcelain insulators for composite insulated current transformers and how these composite insulators will behave in typical busbar arrangements under static and dynamic load conditions.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		15	-1	16
Expected benefits of project	The introduction of composite insulation for post type current transformers is anticipated to eliminate the risk of explosive events occurring, as can occur with the CTs supplied with ceramic insulators. To date failures and risk management have incurred costs in excess of £1m per year. This project will contribute to avoiding future risk management			

	costs (10% is a conservative estimate). The superior pollution performance of composite materials produces a more economic design than porcelain in terms of electrical creepage length and can result in a single standard design as opposed to two designs for different pollution severity levels. There is an additional weight advantage over porcelain which could be utilised when designing the structures supporting the current transformers.		
Expected timescale of project	1Year	Duration of benefit once achieved	5 Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£219k
Potential for achieving expected benefits	The potential for this project achieving the expected benefits is high. The project is expected to provide significant structural data to enable a direct comparison between composite and porcelain insulators. This data will be used to demonstrate that current transformers with composite insulators are capable of being used as a support insulator when used in rigid busbar arrangements.		
Project progress [Year to End of March 2013]	The project was completed in January 2013 and a final report has been submitted to National Grid. The results of the study carried out by Alstom indicated that National Grid could specify current/voltage transformer units with composite insulators without compromising the mechanical strength required to support the various configurations of rigid tubular busbars that would be required. This enabled a specification for composite insulators to be developed which in turn allowed National Grid to purchase 132kV and 33kV HAM units with composite insulators as the safer option for the replacement of the defective population of GEC FMVG units.		
Collaborative partners			
R&D provider	Alstom Grid, Research & Technology, Stafford UK		

<table>
<tr><th>Project title</th><th colspan="4">Long term performance of silicone based composite Insulators</th></tr>
<tr><td>Project Engineer</td><td colspan="4">Boud Boumecid</td></tr>
<tr><td>Description of project</td><td colspan="4">The key objective of this project is to advance the ageing model for composite insulators in order to maximize the return on previous research work in identifying and managing any risks associated with their use on the National Grid electricity transmission system.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £4k
External £31k
Total £35k</td><td colspan="2">Expenditure in previous (IFI) financial years</td><td>Internal £17k
External £364k
Total £381k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£416k</td><td colspan="2">Projected [next year] costs for [company]</td><td>£26k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">This project addresses overhead line insulation systems/asset management implications of using new technology (principally life expectancy and associated ageing mechanisms).</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>12</td><td>3</td><td>9</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The further development of the ageing model will provide National Grid with an asset management tool that enables cost-effective management of composite insulators used on the transmission network. This could lead to significant mid-life refurbishment savings, improved health and safety performance and improved grantor relations. Furthermore, composite insulators are proving to provide better pollution performance than ceramic insulators with a resultant increase in network reliability.</td></tr>
<tr><td>Expected timescale of project</td><td>7 years</td><td colspan="2">Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td>20%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£356k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">Based on the research studies carried out to date, including the fundamental study of the nature of low current discharges on surface insulation this project will allow a better understanding of the low level long term damage caused during the service life of insulators. Also, the work funded by Scottish and Southern Energy on some ex-service insulators has been fed into this project and enabled study of insulators with more advanced ageing. This has shown the importance of the geography of installations and also, because of particular physical features of the insulators, the way in which water movement controls discharge and biofilm development.

The above work has favourably contributed to the increased confidence and high potential in achieving the expected benefits. If composite</td></tr>
</table>

	insulators become a more significant part of National Grid's asset base, this project will have a significantly higher benefit. The work is necessary to establish the introduction the new technology.
Project progress [Year to End of March 2013]	This project continues to underpin the movement towards the use of composite insulators in substations and on overhead lines (including T-pylon and composite cross-arms). The final PhD is now in its third year and is looking at the fundamental mechanisms of surface ageing of polymers. The key challenge being addressed is to understand better the transfer of energy from low current arcs/discharges to the surface of the material. Experimental techniques to measure the temperature of the non-equilibrium arcs using spectroscopy have been developed. This has included the use of EPSRC spectroscopy equipment. Measurements and models of nitrogen temperatures have been used, and in the cases studied rotational temperature is considered as the macroscopic temperature which is equal to the gas temperature. The transfer of energy of the surface of insulators has been directly measured by thermographic measurements of surface temperature and an equivalent finite element analysis model of thermal energy transfer has been developed and is in excellent agreement with the measurements. A direct comparison of AC and DC arcs has been made, shedding light on the aggressive nature of the DC environment. This will shortly be able to give a direct comparison of AC and DC ageing of composite insulators. The output from this work will support development of ageing models and will enable better asset management and product tests to be established.
Collaborative partners	National Grid is currently exploring possible collaborative funding of this project with Scottish Power and Scottish and Southern Energy. Should they agree to support this project it is anticipated that the funding split would be 80 %/10 %/10 % National Grid, Scottish Power and Scottish and Southern respectively.
R&D provider	The University of Manchester

Project title	Strategic R&D
Project Engineers	Jenny Cooper
Description of project	This project is a combination of strategic projects being carried out largely by university groups as part of major strategic collaborations. Projects are supported under EU funding, Electricity Supply Research (ESR) network funding and Engineering and Physical Sciences Research Council (EPSRC) funding in conjunction with contributions from international utilities. The projects focus on understanding the potential of techniques or technologies to impact the electricity Transmission network. Electricity Supply Network - A coordinated network of electricity supply companies which combines links to the majority of electricity research related academic institutions and links to current EPSRC funded energy projects. Projects are identified in the current EPSRC portfolio that are of interest to at least one member company and that the academic is willing to share the project progress. For more information see http://www.nottingham.ac.uk/esr/index.aspx Modelling and control of AC-DC system with significant generation from wind (Imperial) - This PhD project will investigate into the modelling, analysis and control aspects of AC-DC system with synchronous and non synchronous generation. The modelling will be in general multi-machine framework. The expectation is that the HVDC grid side converter control will be supplemented through system level control to mitigate the impact of any time critical dynamic event limiting the transfer capacity of the system. A further research objective is also to see that the undesirable dynamic interaction of the wind generation with a DC link is also controlled through the wind generation side converter system level control. A significant effort in this PhD besides modelling will be concentrated on the control design of these system level controllers for both the converters. Transmission Tower Field Testing and analysis (Southampton) – An EPSRC CASE award to support the longer term aspects of transmission Tower Field Testing and analysis (Dynamic Resistance of Transmission Tower Footings) by addressing the following: • Develop a modern design methodology incorporating field research into rate loading effects and failure mechanisms and to apply these findings in the assessment of existing transmission tower foundations systems. • Identify tools and develop a system for recognising locations and conditions where geotechnical uplift and compression issues are present. UK Infrastructure Transitions Research Consortium (ITRC) Inform the analysis, planning and design of national infrastructure, through the development and demonstration of new decision support tools Transforming Utilities Conversion Points (TUCP) A project aiming to re-think and re-design the conversion points of different utilities. Energy Efficient Cities initiative (EECi) Cross-disciplinary research project aimed at strengthening the UK's capacity to address energy demand reduction and environmental impact in cities.

Undermining Infrastructure Avoiding the Scarcity Trap

To design a truly adaptable, sustainable, low-carbon infrastructure and deliver it without bottlenecks caused by materials scarcity and waste management

Produce Vulnerability Index to quantify the risk posed by resource scarcity to continued operation of existing infrastructure, or the proposed introduction of the new infrastructure.

Shock (NOT) Horror

http://research.ncl.ac.uk/shock/aboutourproject/methodology

The purpose this research two-year project is to study infrastructure shocks through medical allegories will enable a fundamental shift in thinking of current infrastructure to understanding it as a system of systems of infrastructural interconnections that can help foster sustainable futures.

Thus, the aim of this project is to explore trauma as an allegory for infrastructure system shock. The objectives are therefore:

To construct models of systems under trauma;

To use these models to develop models to visualise the socio-technical configuration of integrated infrastructure system;

To test the validity of the allegory of trauma as an allegory of infrastructure system shock;

To ensure that these models reflect the interest and priorities of the relevant stakeholders. To integrate the views of stakeholders.

iCASE Awards:

Techno-economic and reliability analysis of integrated electricity and gas transmission network operation - This joint gas and electricity project aims to extend classical power system models to an integrated electricity-and-gas network operation model that takes into account the current and future (tighter) interactions of electricity and gas systems and the presence of various uncertainties. The impact of such interactions will be analyzed in terms of economics, flexibility, adequacy, reliability, and resilience of the overall energy system (including various possible evolutions for gas sources, the heat sector, and renewables) under future uncertain scenarios.
Geological impacts on the Performance of Subsea HV Transmission Cables The students will acquire, process and analyse a wide range of seismic and geotechnical datasets for HV cable routes across the UK shelf. Particular emphasis will be placed on both the spatial and temporal variability of key parameters such as: mineralogy, grain-size distribution, porosity/permeability, thermal conductivity, bulk density, bed shear stress and erodibility.
Electromagnetic Transients in Evolving Grids The key objectives that will be delivered by completing this work will be:

- Assessing the suitability of the existing safety clearances for standard maintenance practices and live line work
- Highlighting threats associated with overvoltages in terms of the reliability of the present and future power system
- Identifying opportunities to reduce overvoltage withstand levels and increase system compactness.

Time and frequency domain analytics for distributed sensors embedded in

	plastic optical fibres. Fibre distributed sensors present a great opportunity for monitoring long extents of networks and related infrastructure. In particular, Plastic Optical Fibres, which are not only biologically safe insulators and are easy to handle, allow high sensitivity detection of strain and mechanical vibrations. More importantly, when Plastic Optical Fibres are sensitised in specific areas, targeted distributed sensors can be produced. Wireless energy harvesting sensor arrays based on photonic interrogation of sensitised optical fibres The case award will allow for an investigation into current technologies involving energy harvesting and their integration into photonic systems. This undertaking would then provide a new development allowing for a novel integration of optically interrogated fibre sensors into wireless energy harvesting systems. The modality proposed would facilitate the monitoring of processes which are of relevance to National Grid.		
Expenditure for financial year	**Internal £28k** **External £127k** **Total £175k**	**Expenditure in previous (IFI) financial years**	**Internal £113k** **External £365k** **Total £478k**
Total project costs (collaborative + external + internal)	**£12m estimated**	**Projected 2013/14 costs for National Grid**	**£101k**
Technological area and/or issue addressed by project	Electricity Supply Network – Projects areas currently being monitored by National Grid through the network include Knowledge Discovery from On-line Cable Condition Monitoring Systems – Insulation Degradation and Aging Diagnostics (Glasgow Caledonian University and the University of Strathclyde), Energy Efficient Cities (University of Cambridge), Development of Transformer and Fault Current Limiter for High Power DC Networks (University of Aberdeen), Energy Loss Study for AC Excited Superconducting Coils (University of Cambridge) and Control For Energy and Sustainability (Imperial College). Modelling and control of AC-DC system with significant generation from wind - In 2008 alone 2000 MW of new wind capacity was connected to the UK grid. With further 6000 MW under construction and 10,000 MW under planning stage in the first round, the UK transmission system in the next 5-10 years is going to face unprecedented operational challenges. The challenges are envisaged to be contributed by many factors such as locations, characteristics of new generation and planned retirement of more and more centralised synchronous generations. As majority of the wind uptake is going to be in North West of Scotland and demand growth will still be dominated in the down south in England, secured transfer of the energy is going to be a major problem across the Scotland-England inter connector which is already stability limited. Transmission Tower Field Testing and analysis -Following previous work there is an understanding of the uplift capacity of National Grid's existing transmission tower foundations under steady state and dynamic loading conditions. Climate Change and Resilience projects – Anticipated outputs will impact sustainability agenda. iCASE awards:		

	Techno-economic and reliability analysis of integrated electricity and gas transmission network operation - Amongst other questions, it will be assessed how smart management of both networks could support the development of clean energy scenarios beyond the traditional electricity-only Smart Grid vision. The project will interact with a number of existing projects, including the Autonomic Power Systems Grand Challenge, HubNet, and RESNET. Geological impacts on the Performance of Subsea HV Transmission Cables Data both pre- and post-installation will be investigated to look at both the impact of trenching and backfill on these key physical parameters and the variability of these parameters with the changing thermal regime. Electromagnetic Transients in Evolving Grids With the move to new transmission system technologies and the possible use of live line working on both overhead lines and substations, it is timely and important to review the magnitude and frequency of transients. Of particular importance are switching transients that in the majority of cases drive the need for safety clearances and have an impact on equipment reliability. Time and frequency domain analytics for distributed sensors embedded in plastic optical fibres. This project will aim at allowing the monitoring of environmental variables (initially temperature, moisture, etc.) along a process or equipment stretching for an extended length such as pipelines, canals, lengths of live cables etc. Sensors which can detect specific gases will also be trialled with a view of producing a distributed geometry with multiple types of sensors positioned along the fibre media at known sections. Plastic optical fibres do not conduct electricity and the optical interrogation provides a safe spark free means for recording sensor data. Wireless energy harvesting sensor arrays based on photonic interrogation of sensitised optical fibres Wireless Energy harvesting sensor systems are becoming an established technique for developing environmental awareness of the functionality of processes and systems. They can be retrofitted and function in a decoupled manner to the functionality of the monitored or assessed systems and have a small footprint. A capability which independently assesses the environmental conditions in the immediate vicinity of a given process greatly enhances operational safety, reliability, and awareness of the ongoing environmental processes.			
Type(s) of innovation involved	Radical	Project Benefits Rating	Project Residual Risk	Overall Project Score
		6	4	2
Expected benefits of project	Electricity Supply Network and EPSRC projects – The outturn from the managed EPSRC projects is an awareness of current research issues and potential to implement via addition IFI projects, for example via application of condition monitoring developments. Modelling and control of AC-DC system with significant generation from wind - While the dynamic consequence of Scottish and English interconnected AC system is well understood and can be managed by generator additional control (power system stabilizer) the dynamic performance of the system in the presence of wind generation and HVDC transmission is not well investigated. Existing research in wind generation modelling addresses the dynamic and control performance of wind generator connected to the AC grid. The			

	modelling details of the grid is neither very comprehensive nor in multi machine small signal stability framework which is often necessary for planning studies for the interconnected utilities. Inclusion of HVDC link adds further complexities giving rise to difficult research issues. Through networks such as the Electricity Research Network access is gained to government funded research with potential impact to the networks. Not only is there the potential to be made aware of new knowledge and technology but also the potential for National grid to inform and influence the research of large collaborative projects leading to more successful research with potential future impact to consumers. Transmission Tower Field Testing and analysis - Assist in the interpretation and implementation of UK and European standards into general National Grid specifications, in particular relating to geotechnical and overhead line foundation design and testing. Climate Change and Resilience projects – Research findings will form the basis of knowledge to be applied by National Grid with respect to sustainability. Key focus is knowledge transfer to National Grid staff. iCASE Awards Research will increase knowledge in project areas and if applicable develop into a specific innovation project for development if of direct benefit to National Grid's network		
Expected timescale of project	Ongoing	Duration of benefit once achieved	5+ years
Probability of success	25%	Project NPV = (PV benefits – PV costs) x probability of success	-£319k
Potential for achieving expected benefits	Although speculative or strategic by nature, these projects are expected to feed in to National Grid through knowledge transfer from typically academics to the relevant specialist engineer. The work is expected to form the basis of further research or developments, most likely as a specific project.		
Project progress as of March 2013	Electricity Supply Research Network – Knowledge Discovery from On-line Cable Condition Monitoring Systems – Insulation Degradation and Aging Diagnostics, Prof C Zhou (Glasgow Caledonian University) and Dr M Judd (University of Strathclyde) - a very interesting project, which is progressing well. It has however met difficulties and delays due to changes in support and staff. Reported via condition monitoring engineer. Transmission specific progress via FDTD modelling. The role of the semiconductor layers is critical and modelling it by constant permittivity and conductivity, independent of frequency, does not properly simulate actual PD propagation. The building blocks needed to construct the complete time-domain transfer function from PD current pulse through the cable to the CT output voltage are now complete and integrated. A transmission line model has also been developed for use on longer cables, as only up to 12 m of cable can be fully modelled, due to the computational load. Energy Efficient Cities, Prof I Leslie, University of Cambridge. This very large project is now holding six monthly seminars, which ESR Network are invited to. The individual strands of the project are progressing very well, but the challenge will be to bring them together.		

Development of transformer and Fault Current Limiter for High Power DC Networks, Dr D Jovcic, University of Aberdeen. The project is progressing well with the three member companies attending progress meeting. DC Grid development is according to plan with prototypes and convertor design completed. 3 journal articles and 3 conference articles completed. Studies are ongoing on developing DC grids with LCL VSC converters.

Energy Loss Study for AC Excited Superconducting Coils, Dr Tim Coombes, University of Cambridge. An interesting research project to maintain a watching brief on topic, progress meetings attended.

Modelling and control of an ACDC system with significant generation from wind - Modelling of an AC and an ACDC network with a current source converter link have been conducted in Power Factory and Matlab, for comparison. Some Matlab simulations have been conducted on a DC link with voltage source converts. These simulations were conducted to solve load flows within ACDC networks.

Furthermore wake simulations on a wind farm were developed in Matlab. The simulations take the operating regime of the wind turbine into account. Results are shown for each wind turbine and for the whole farm, for 12 sectors of wind directions.

The work included the submission of an initial research plan and technical report to Imperial College.

The Development of an Equivalent Power Network Model for HVDC Studies – This project links with the HVDC work reported under the EPRI project with results and knowledge being utilised in the design and planning of the Weatern and Eastern HVDC links.

Transmission Tower Field Testing and analysis - The design has been completed and a scale model built feeding in to verifying the main project outcome (reported separately).

UK Infrastructure Transitions Research Consortium (ITRC)

Two Energy workshops have been held with National Grid sharing information on the National Grid 2020/2050 Energy Scenarios. The project has developed a better understanding on the 2020/2050 demand /Supply scenario. A fast track analysis of strategies for infrastructure produced. ITRC consultation briefing document on new methodology and system simulation models is under discussion. Data Integration is ongoing for the Energy Sector on this project.

Transforming Utilities Conversion Points (TUCP)

A second version of the model produced. It shows the effects of consumer choices in the selection of infrastructure agents – effects being overall efficiency, use of resources, cost of utility provision. Demand agents switch to alterative infrastructure providers who are a better fit for their objectives (price and greenness). The model is conceptual at this stage and to implement it for a real location requires a serious amount of data collection. The project end date was extended from mid-March to mid-September

Energy Efficient Cities initiative (EECi)

They are now in the final year of the project and are devoting significant efforts towards integration of the research tools and models that have been developed. As a part of these efforts they have begun to apply models and analyses on a single geographic area, around Paddington Station London, as a way to focus our efforts in examining compelling

	questions that can only be addressed through joint analysis. Through these studies they are able to investigate the combined effects of buildings, transport and land use on energy, air quality and climate change.Final documents are being prepared for the project closure. Undermining Infrastructure Avoiding the Scarcity Trap National Grid has provided a set of slides identifying issues that concern us with respect to this project. Shock (NOT) Horror A workshop has been held to examine three sectors: Energy, Transport and Water under 3 headings of 1. Landscapes of Infrastructure 2. Infrastructure SHOCKS 3. Resilience infrastructure All the above three sectors were then assessed in terms of socio technical transitions under three headings of • Landscape • Regime • Niche iCASE Awards Projects initiated at end of 2012, no significant progress to date.
Collaborative partners	EPSRC, ENW, SSE, EoN, Alstom Grid, Dooson Babcock, National Grid Gas Transmission
R&D providers	Manchester University, Imperial College, University of Strathclyde, Southampton University. ECAS

Project title	33kV Fault Current Limiter		
Project Engineer	Barry Reeves		
Description of project	Key learning to be delivered by the project is the understanding of the circumstances under which the superconducting fault current limiter (SCFL) can be used to mitigate fault level issues which are a barrier to distributed generation (DG) connection and how the SFCL can then be designed and operated. Specifically the following learning outcomes would be expected: • Identification of network and physical circumstances where use of the SFCL could be used to mitigate fault level issues and address potential future DG connection issues. • Identification of design, construction, commissioning, protection, control and operational issues associated with use of such equipment. If the trial proves successful in mitigating faults this could also reduce the need for transmission reinforcements across the UK. • Assessment of actual carbon benefits/confirmation of initial carbon case. • Assessment of impact of equipment on policies, codes of practice, section level procedures, financial authorisation processes (including the financial justification) and identification of required revisions. • Dissemination will be through the production of a "how to" manual that details the new knowledge outlined above. Demonstration Objectives This project trials a specific piece of new equipment that has a direct impact on the operation and management of the distribution system and potentially the transmission system. Phase 1: to identify suitable locations for the SFCL installation and undertake a feasibility and systems readiness study to analyse the network, outline the optimum application and specification, and confirm the business and carbon cases. Phase 2: is to design, build, install and commission a three-phase 33kV SFCL on the CE distribution network. It is proposed, subject to site surveys and agreement with National Grid and other partner organisations, that the unit is installed at a 275/33kV substation in South Yorkshire to limit the fault current to within the rating of the 33kV switchgear. This is currently managed through an operational management switching procedure which in some circumstances may increase the risk of loss of supplies to customers.		
Expenditure for financial year 11/12	Internal £21k External £53k Total £73k	Expenditure in previous (IFI) financial years	Internal £37k External £1k Total £38k
Total project costs (collaborative + external + [company])	£2,921k	Projected 2013/14 costs for National Grid	£7k

Technological area and/or issue addressed by project	The Government's targets for reducing carbon emissions mean the UK needs to reduce its dependence on fossil fuels and adopt cleaner energy sources. Generators using renewable energy are sited near their energy sources (on hills for wind, by the sea for tidal and wave power, near landfill sites or digesters for gas, etc). Combined heat and power schemes, which recover waste heat from the process of generating electricity, need to be installed in locations where there is a need for heat. These sites are rarely connected to the National Grid system and in any case connecting to this voltage level would be unfeasible for generators of moderate capacity (typically under 50MW) which are likely to be connected in Sheffield. Generator connections are therefore being made to local distribution networks that have limited capacities to handle short circuit fault currents. To facilitate the connection of generation from renewable sources at the distribution voltage level, the network needs to be capable of withstanding these consequential increases in fault level. Traditional approaches to managing increasing fault levels lead to time consuming, costly infrastructure upgrades which may cause the proposed generation development not to proceed. The project is largely funded by the Low Carbon Network Fund (LCNF), with assumed costs of superconductor fault limiter is in the order of £2m, which has been made available by Ofgem. The LCNF project will pay for the superconducting fault current limiter and the monitoring and testing of the system. Sheffield 275kV ring main was selected due to the following reasons: • Alleviate immediate fault level issues so that operational restrictions may be removed and existing 33kV and 11kV switchgear may continue to be used and operated as originally envisaged. • Improve the network resilience to 33kV faults whilst the operational procedures associated with the restrictions are being implemented. • Facilitate the connection of distributed generation without triggering fault level concerns. • Allow the 33kV network to be run with some of the interconnection circuit breakers operated normally closed, to increase load capacity. Jordanthorpe was selected as the site for the trial. Jordanthorpe is a 275/33kV substation equipped with two 100MVA transformers connected to the 275kV network. At 33kV, Jordanthorpe can be connected via an intermediate substation to Norton Lees Substation. The 33kV AEI switchgear board has one bus section but there is no spare breaker. It is situated on the southern edge of the city in an almost rural location with space to install additional equipment.			
Type(s) of innovation involved	Technological substitution	Project Benefits Rating	Project Residual Risk	Overall Project Score
		6	-6	12

Expected benefits of project	**The benefit to National Grid is understanding the integration of a super conducting fault current limiter into the electricity transmission network and its impact on the distribution systems and, in particular, potential scalability to a transmission size super conducting fault current limiter.** **This project has large potential benefits for the customer, if the trial proves successful in mitigating faults, through the potential to connect generation to the electricity system without large modification to the existing system, minimizing costs and disruption to customers.** **Also as part of National Grid's innovation Strategy, this project addresses a reputational issue of driving the carbon agenda with the support of our distribution colleagues, ensuring that the energy industry is seen to be making headway into the reducing carbon dioxide emissions and facilitating the changing energy market.** **This project aims "To facilitate the connection of generation from renewable sources at the distribution voltage level, the network needs to be capable of withstanding these consequential increases in fault level. Traditional approaches to managing increasing fault levels lead to time consuming, costly infrastructure upgrades, which may cause the proposed generation development not to proceed."** **The deployment of an SFCL (assumed total costs of this demonstrator project of £2.6m) will have the following (multiple and overlapping) technical and commercial benefits to operators and owners of electrical networks by:** **1. Observing this development on the Distribution system tol learn (from a technology and a business perspective) whether or not it could be scaled up for application at Transmission voltages.** **2 Speeding up the connection of Distributed Generation at 6.6kV – 33kV (ultimately at higher voltages) and eliminating the costs of network reinforcement associated with rising fault levels. This also supports the use of locally available primary energy resources.** **3. Reducing losses. They allow the network to be interconnected (meshed) without replacing switchgear to cope with rising fault levels. Meshed networks generally have lower losses and more load capacity headroom, allow for improved power quality (due to lower network impedances at times other than at times of network faults) and availability. Application of SFCLs will allow the use of lower impedance transformers in asset replacement / reinforcement schemes and removal of series reactors both of which would reduce network losses.** **4. Reducing asset management costs whilst improving network safety, stability and efficiency. SFCLs should be able to offer lower cost alternatives compared to conventional means of reinforcing and maintaining fault levels at an acceptable level.** **5. Bi-directional fault flow in smart networks arising from the connection of distributed generation can have an adverse impact on the performance of some protection schemes. Depending on the relative magnitude of the fault currents from generation and the transmission system, application of SFCLs can improve the capability of an existing protection system to cater for increased levels of distributed generation. For Transmission protection, it may be possible to take advantage of changed settings and reduce the impact of faults on other network equipment or unforeseen impacts may be determined for which mitigation will be needed.** **6. Allowing for a safe and sustainable solution at substations where reinforcement related time constraints could defer a generation**

	connection. 7. Allowing for increased overall network lifetime and reduced likelihood of subsequent faults, as a result of limiting short circuit currents rather than installing higher rated equipment to cater for them.		
Expected timescale of project	**1 year**	**Duration of benefit once achieved**	**8 years**
Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**-£313k**
Potential for achieving expected benefits	**There is a strong likelihood of success of the trial succeeding in obtaining applicable and transferable knowledge, however, there is a low likelihood that this project will be scalable to the transmission system.**		
Project progress [Year to End of March 2013]	**The detail design is almost complete i.e. how is the SFCL going to be physically connected into the HV system and the protection systems at Jordanthorpe.; however there is an issue on the level of DC electromagnetic fields exceeding guide line limits. This is only an issue for people with pace makers. A solution is being progressed with National Grid, ASL and Northern Powergrid (NPG). There were many meetings with NPG to discuss what would be needed to protect National Grid's and the NPG's existing assets if the SFCL were to fail in service. A set of test requirements for the SFCL, short of type registration, but following the principles of type registration, have been agreed with NPG and the supplier ASL..** **The HAM unit Risk Hazard Management Zone (RHMZ) caused significant issues. As outages could not be secured to replace the two sets of HAM units that are impacting on the access road and the SFCL construction area, ballistic screening of these areas was the only option left. This was progressed but the screening needed to sit inside the RHMZ, therefore outages would have still been needed to allow installation.** **In 2013, the HAM units were replaced therefore removing the Risk Hazard Management Zones around both SGT1 and 2. The main outages had been agreed but as the HAM replacement dates slipped due to outage constraints, the SFCL installation date needed to be delayed later in the outage year. Discussions are still ongoing.**		
Collaborative partners	**Low Carbon Network Fund**		
R&D provider	**Applied Superconductor Limited**		

Project title	Trial & Performance Assessment of ACCR Conductor (3M)			
Project Engineer	Mike Fairhurst			
Description of project	Assess the suitability of the new generation of high temperature low sag overhead line (OHL) conductors currently available on the market, for deployment on the UK transmission network, in terms of mechanical capability & performance, erection methods, maintenance & repair. At present National Grid have installed both GAP and ACCC (CTC) conductors on the bottom & middle phase on the de-commissioned YYO line near Sheffield in order to evaluate the mechanical performance. The goal of this project is to string ACCR (3M) on the remaining top phase in order to evaluate and compare the stringing, sagging and termination of these three high temperature low sag (HTLS) conductor types, to monitor their mechanical behaviour during simulated ice loading conditions and to evaluate the practical application of the three. HTLS conductors and their component materials have been extensively tested both during and after their development by the manufacturers and various research organisations, but to date National Grid have yet to carry out such works.			
Expenditure for financial year 11/12	Internal £21k External £22k Total £42k	Expenditure in previous (IFI) financial years	Internal £5 External £150 Total £155	
Total project costs (collaborative + external + [company])	£385k	Projected 2013/14 costs	£0k	
Technological area and/or issue addressed by project	There are many sorts of power flow limitation in modern power systems. If the problem can be solved by a relatively large increase in the thermal rating of an overhead line, re-conductoring the line with HTLS conductor is a possible solution. These conductors are capable of high temperature operation with minimal change in electrical and mechanical properties and have low sag at high temperature when compared to conventional conductors. In order to increase a line's thermal rating without rebuilding or replacing its structures and foundations, the original conductor can be replaced with a special high-temperature, low-sag (HTLS) conductor having the similar dimensions and properties as the original, but which can be operated safely and reliably at much higher temperatures with far greater ampacity. ACCR conductor has over 10 years service history with no reported failures in service and no failures during installation. To date there are 90 successful installations, in over 60 different countries, with more scheduled for 2011, 2012 & 2013. With the most recent installation being in National Grid USA, as part of the Western Massachusetts Transmission Reinforcement Strategy, 3M are currently investing in expanding manufacturing capacity to meet demand.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score

		13	1	12
Expected benefits of project	The advantage of the high temperature low sag conductors is their ability to operate continuously at temperatures of 150°C or above with less increase in sag and little or no loss of strength, the net result being increased line rating from existing assets Manufacturer tests of ACCR (3M) indicate that it can be operated at 210°C continuously without changing its mechanical or electrical properties, with a post fault temperature of 240 °C. Providing increased capacity on existing overhead line routes and increased operational flexibility of the network under post fault conditions. The initial cost is considerably more than conventional conductor systems (5 times), however a proportion of this cost will be off set by eliminating the requirement to strengthen existing towers and foundations as is currently the position when existing lines are up-rated, with larger heavier conductors (nominally £30 - £40k per tower), estimated in the forward planning to 2021 as 950 circuit km (nominally 3 towers per km leading to potential £100m saving on towers offset by increased conductor costs resulting in a conservative £10m benefit).			
Expected timescale of project	2 years	Duration of benefit once achieved	8 years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£3,189k	
Potential for achieving expected benefits	As stated earlier many countries around the world are adopting this new technology with much design review and testing. With respect to the ACCR (3M) conductor there have been no reported problems since the earliest installation some 10 years ago. National Grid in the US is currently refurbishing and re-conductoring a 110kV line in Massachusetts.			
Project progress [Year to End of March 2012]	The original deployment was to be on a disused section of line (YYO) however site issues led us to abandon that site as the testing facility. As an alternative, the conductor was erected at National Grid training facility at Eakring. All accessories and conductor underwent mechanical testing. National Grid in association with 3M erected the curlew conductor on the top phase of the training line at Eakring with no major issues. Following the initial success of the R&D project, an opportunity arose to erect the same curlew conductor on the High Marnham-West Burton upratings scheme (originally planned for GAP conductor). This presents an ideal opportunity to compare 2 new conductor types as the adjacent Cottam-West Burton circuit is strung with the CTC (ACCC). The 3M conductor is now erected on this circuit, and is due to be commissioned w/c 17th June 2013. Both conductor systems will be monitored simultaneously for medium to long term performance.			
Collaborative partners				

R&D provider	**3M**

Project title	**Power Networks Research Academy**		
Project Engineers	**Jenny Cooper,**		
Description of project	**The Power Networks Research Academy (PNRA) has been established through a strategic partnership agreement between the Engineering and Physical Sciences Research Council (EPSRC), electricity transmission and distribution companies, related manufacturers and consultants, that will fund and support PhD researchers in power industry related projects and help maintain and improve the research and teaching capacity in power engineering subjects.**		
Expenditure for financial year	**Internal £6k** **External £40k** **Total £45k**	**Expenditure in previous (IFI) financial years**	**Internal £15k** **External £212k** **Total £227k**
Total project costs (collaborative + external + internal)	**£10,270k**	**Projected 2013/14 costs for National Grid**	**£0k**
Technological area and/or issue addressed by project	**PhD Award Holders** **Details of research projects, the lead academic, the university and the name of the PhD award holder are set out for each of the years below, National Grid supported projects highlighted:**		

Project Title	Lead Academic	University	PhD Scholar
Overhead Lines Measurement System (OHMS)	Manu Haddad	Cardiff	Stephen Robson
Application of Artificial Immune System Algorithm to Distribution Networks	Jovica Milanovic	Manchester	Nick Woolley
System Impacts and	Tim Green	Imperial	Yousef

Opportunities of HVDC Upgrades		College	Pipelzadeh
Protection Issues of Inverter-Interfaced DG	Tim Green	Imperial	Nathaniel Bottrell
Electrical Network Fault Level Measurement For DG and other applications	Andrew Cruden	Strathclyde	Steven Conner
Reactive Power Dispatch for Distributed Generation	John Morrow	Queens	Stephen Abbott
Protection of future power systems encompassing DG, converter interfaces and energy storage	Campbell Booth	Strathclyde	Kyle Jennett
Intelligent Insulation Systems	Paul Lewin	Southampton	Alex Holt
Early Frequency Instability Measurement	Vladimir Terzija	Manchester	Peter Wall
Protection of Series Compensated	Vladimir Terzija	Manchester	Shantanu Padmanabhan

Transmission Lines based on synchronised measurement technology			
Influence of oil contamination on the electrical performance of power transformers	George Chen	Southampton	Shekhar Mahmud
Alternatives to SF6 as an insulation medium for distribution equipment	Manu Haddad	Cardiff	Phillip Widger
Reducing the risk of sub-synchronous resonance in meshed power networks with increased power transfer capabilities	Jovica Milanovic	Manchester	Atia Adrees
Solid state devices for electrical power distribution	Stephen Finney and Tim Green	Strathclyde Imperial	Gordon Connor -April 2011 start
LV Cable Monitoring Using Domestic Smart Meters	Simon Rowland & Peter Green	Manchester	Berihu Mebrahtom
Effect of climate change on design and operation of meshed networks	Keith Bell	Strathclyde	Kirsty Murray

State Estimation for Active Distribution Network	Bikash Pal	Imperial	Sara Nanchian	

Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score
		2	-2	4

Expected benefits of project	It is expected that the Academy will: • promote a stronger, more active and robust R & D environment in power networks disciplines at UK universities; • provide capacity and capability to undertake the specialist research needed by industry and wider stakeholders; • strengthen the teaching capability at those institutions; • focus on building the health of discipline across a number of power research universities; • facilitate a resource of trained engineering staff with academic capability, who will be capable of tackling electrical power engineering challenges; and • deliver research output that is industrially relevant. See online for further information at http://www.theiet.org/about/scholarships-awards/pnra/

Expected timescale of project	5 Years	Duration of benefit once achieved	5+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£172k

Potential for achieving expected benefits	The potential for achieving the benefits are high. It is expected that the PNRA will achieve the expected benefits.
Project progress as of March 2012	Since 2008 eighteen projects for PNRA scholars have been selected from a number of submissions, using a two tier process. This process comprised; an initial sift to determine the project's industrial relevance and an independent peer review to determine their academic excellence. Scholars were subsequently recruited and a brief summary of the progress on National Grid supported transmission projects achieved to date are detailed below. National Grid also receives benefit from the DNO supported projects, most applicably the

Alternatives to SF_6 as an insulation medium for distribution equipment at Cardiff University which will be considered as part of National Grid's review of alternatives to SF_6.

System Impacts and Opportunities of HVDC Upgrades (Yousef Pipelzadeh, Imperial College, London)

A major change in generation mix and demand growth is anticipated by 2020 in the GB network, with 35% of total energy demand to be supplied by renewable generation. This includes an additional 45 GW of power generation.

The major generation supply (Wind generation in particular) is in the North, whilst the demand is predominately in the South. The circuits between these regions operate near their maximum transfer stability limit and the prospect of overloading the transmission network in GB demands major transmission network reinforcements to accommodate the anticipated growth. Managing this change will require the electricity industry to tackle new legal, technical, commercial and regulatory challenges.

Its envisaged that the feasible options are first to maximise the utilisation of the existing assets through installation of series compensators within the stressed 275 kV Scottish/English corridors resulting in boundary flows between regions to operate closer to the thermal capacity and second, exploit the latest technological solutions to ensure demand is met with minimal environmental impact. As such High Voltage Direct Current (HVDC) is envisaged to play a vital role to meet this target.

In light of these system reinforcements, the project attempts to address some of the technical challenges in improving the angular stability and system security be means of intelligent supplementary control techniques acting through HVDC devices.

The expected benefits of the project are

1) The modelling and control of (i) Line Commutated Converter (LCC) and Voltage Source Converter (VSC) based HVDC transmission networks, (ii) Offshore wind farms connected via HVDC links and, (iii) small to large scale study systems in PowerFactory DIgSILENT.
2) Develop a tool to identify the poorly damped low-frequency modes of large-scale transmission networks using wide-area monitoring signals. The tool should be capable of accurately providing linear models.
3) Demonstrate the opportunities for both LCC and VSC based HVDC links for damping low frequency power oscillations using wide-area signals, thereby increasing the transfer capacity of host AC networks.
4) Develop a practical (robust, low-order, distributed and coordinated) control scheme for supplementary damping control within VSC HVDC links.
5) Demonstrate coordinated control of offshore wind farms and VSC-HVDC links for effective power oscillation damping.
6) Investigate the impact of significant wind penetration and HVDC upgrades on the stability of future grids.
7) Development a method to allow for inertial response from remote offshore wind farms connected through VSC-HVDC links without the need for communicating the grid frequency to the offshore site.

Identification of reinforcement opportunities through coordinated control of Wind-Farms and HVDC, TCSC, etc. in GB network

Progress in the period April 2012 – March 2013

The project has demonstrated that when DC links are used to relieve a constraint in a weak transmission corridor there can be additional benefit beyond the simple additional capacity in that the damping of inter-area modes can be improved and the stability constraint on AC transfers raised significantly. This finding is very relevant to the GB context given that, during the life of the project, a firm plan to build a western bootstrap DC link from Scotland to England was formed.

The work has examined approaches to allocating control duties between control signals (real and reactive powers of more than one converter station, for instance) and has examined ways to improve the robustness to communication failure through choice of complimentary feedback signals and various treatments of the multiple-input, multiple-output control problem.

The work has been conducted using the DiGSILENT PowerFactory software so as to be compatible with National Grid. Control systems designs have been verified in full nonlinear time-step simulations. Since no GB-like model was forth coming, the verification was conducted on a representation of the Australian system.

The work was extended to consider damping services from offshore wind farms connected via HVDC and this has proved of interest to National Grid and has been taken further forward through a study via EPRI and a consultancy project directly with Imperial.

Specific dissemination:

1. Completed a 3 months placement within National Grid (Warwick) in 2010. Developed standard HVDC models in DIgSILENT and compared performance against models provided by National Grid. Prepared several reports for National Grid focused on the HVDC models and operation of DC/AC networks.

2. Presented the research developments from the PhD project on several occasions to industry, which include National Grid (in presence of companies such as GE, Vestas, and Dong Energy etc), Scottish Southern Energy (SSE) and Parsons Brinckerhoff.

3. The outcome of the PhD work has been followed by a collaborative project with Electric Power Research Institute (EPRI) of USA. Further, National Grid has engaged Imperial to work on a project concerning to offshore networks.

Reports:

Internal National Grid technical reports.
Contributions to standards and professional body reports e.g. Cigre publications, CIRED publications, IET reports, etc.

- **Technical report for Electric Power Research Institute (EPRI) 'Integration of HVDC in an AC grid: Theoretical developments', 2012.**
- ***Y. Pipelzadeh , B. Chaudhuri, and T.C. Green,* "Control Coordination of VSC- HVDC Link for Power Oscillation Damping: A Robust Decentralized Approach Using Homotopy," IEEE Transactions on Control System Technology, DOI: 10.1109/TCST.2012.2202285, 2012**
- ***Y. Pipelzadeh , N. R. Chaudhuri, B. Chaudhuri, and T.C. Green,* "System Stability Improvement through Optimal Control Allocation in VSC HVDC Links," IET - Generation, Transmission and Distribution, Vol. 6, No. 9, pp. 811-821, DOI 10.1049/iet-gtd.2011.0828, 2012**

- ***Y. Pipelzadeh , N. R. Chaudhuri, B. Chaudhuri, and T.C. Green,*** **"Coordinated Control of Offshore Wind Farms and VSC-HVDC Links for Effective Power Oscillation Damping," IEEE Transactions on Power Systems, to be submitted.**
- **Y. *Pipelzadeh, R. Moreno, B. Chaudhuri, G. Strbac, T.C. Green,* "An Assessment of Transient Assistive Measures Using HVDC for Special Protection Schemes: Case on the GB Transmission System", *in proceedings of IET ACDC 2012, Birmingham, United Kingdom*, 2012.**
- ***Y. Pipelzadeh, B. Chaudhuri, and T.C. Green*, "Inertial Response from Remote Offshore Wind Farms Connected Through VSC-HVDC Links: A Communication-less Scheme," IEEE PES General Meeting, San Diego, California, DOI 10.1109/PESGM.2012.6345609, 2012**
- ***Y. Pipelzadeh, B. Chaudhuri, and T.C. Green*, " The Impact of Significant Wind Penetration and HVDC Upgrades on the Stability of Future Grids: A Case Study on the Australian Power System," *in proceedings of CIGRE International Symposium, Bologna*, 2011.**
- ***Y. Pipelzadeh, B. Chaudhuri, and T.C. Green, "*** **Coordinated Control of Offshore Wind Farms and VSC-HVDC links for Effective Power Oscillation Damping", *Cigre-UK*, Staffordshire, Sept 2011**
- ***Y. Pipelzadeh,*** **B. Chaudhuri, and T.C. Green, "Coordinated Damping Control Through Multiple HVDC Systems: A Decentralized Approach," *in proceedings of 2011 IEEE PES General Meeting, Detroit, Michigan*, DOI 10.1109/PES.2011.6039663 2011.**
- ***Y. Pipelzadeh*, B. Chaudhuri, and T.C. Green, "Decentralized Control for Damping Multi-Modal Oscillations through CSC/VSC HVdc Transmission Technologies," *in proceedings of IET ACDC 2010 ,London, United Kingdom*, 2010.**
- ***Y. Pipelzadeh,*** **B. Chaudhuri, and T.C. Green, " Wide-area Power Oscillation Damping Control through HVDC: A case study on the Australian equivalent network," *in proceedings of 2010 IEEE PES General Meeting, Minneapolis, Minnesota*, 2010.**
- ***Y. Pipelzadeh,*** **B. Chaudhuri, and T.C. Green, " Stability Improvement through HVDC Upgrade in the Australian Equivalent System," *The* 45*th International Universities' Power Engineering Conference, Cardiff, Wales,* 2010.**

Early Frequency Instability Predictor Based on Synchronised Wide Area Measurements - E-FIP (Peter Wall, Manchester)

The goal of the E-FIP project is development of a new tool that will support frequency control. The tool will provide this support by predicting the post-disturbance frequency behaviour. Where, a disturbance is a significant change in the active power balance of a system. Examples of a disturbance include the disconnection of a generator or a large change in load. This prediction of frequency behaviour should allow the system operator to optimise the actions taken to control any deviation in frequency.

The expected benefits of the E-FIP tool are enhanced transmission system

performance, in the form of:

- **Reduced stability margins**
- **A significant reduction in the investments made in procuring frequency response support.**

The methods currently being considered depend upon the value of system parameters that may be difficult to estimate in the time available after a disturbance. This dependence does cast some doubt on the potential realisation of the expected benefits. Although with the time available it is likely that this problem can be overcome.

A model based method for estimating the magnitude of the steady state frequency deviation that will occur after a disturbance has been developed.

A literature review of direct methods for stability assessment, based on an energy function, is in progress. Based on the current state of this review it appears possible that a direct method can be employed, if a suitable energy function can be produced.

Work has continued on inertia estimation. This has focused on dealing with some of the issues that make practical implementation of inertia estimation difficult and has produced some promising, although only initial, results.

Progress in the period April 2012 – March 2013 has been:

Successful demonstration of the application of pattern classification to frequency prediction.

Creation of an online, measurement based, method for predicting the frequency based on approximate models

Completion of thesis.

Publications/dissemination

- **L.Ding, F.Gonzalez-Longatt, P.Wall, and V.Terzija, "Two-Step Spectral Clustering Controlled Islanding Algorithm", *IEEE Trans. on Power Systems*, Volume: PP, Issue: 99, DOI: 10.1109/TPWRS.2012.2197640, 2012, (IEEE EARLY ACCESS ARTICLE)**
- **F.M.González-Longatt, P.Wall, P.Regulski, V.Terzija, "Optimal Electric Network Design for a Large Offshore Wind Farm Based on a Modified Genetic Algorithm Approach", *IEEE Systems Journal*, Volume: PP , Issue: 99, 2011, DOI 10.1109/JSYST.2011.2163027.**
- **Wall, Peter; Gonzalez-Longatt, Francisco; Terzija, Vladimir; , "Estimation of generator inertia available during a disturbance," *Power and Energy Society General Meeting, 2012 IEEE* , vol., no., pp.1-8, 22-26 July 2012 doi:10.1109/PESGM.2012.6344755 URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6344755&isnumber=6343905**
- **Wall, P.; González-Longatt, F.; Terzija, V.; , "Demonstration of an inertia constant estimation method through simulation," *Universities Power Engineering Conference (UPEC), 2010 45th International* , vol., no., pp.1-6, Aug. 31 2010-Sept. 3 2010 URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5649023&isnumber=5648789**

In addition, two more Journal papers are submitted and are currently under review.

Protection of Series Compensated Transmission Lines Based on Synchronised

Measurement Technology (Shantanu Padmanabhan, Manchester)
Transmission networks across the world face the challenge of increasing electricity demand requiring an increased power transfer capacity for the transmission lines. More specifically to UK, a large amount of distributed generation is expected to be connected to the Great Britain transmission network as a part of vision 2020. The large distances between the distributed generation and the load centres can be met provided the transmission capacity of the system is increased. Series compensation provides an effective solution to this problem and also provides increased transient stability to the system. Series compensation may be in the form of Fixed Series Compensation (FSC) or Thyristor Controlled Series Compensator (TCSC). There are however, a number of problems associated with series compensated lines such as protection and fault location. The changing impedance of the series compensators during the fault makes it very hard for conventional impedance based protection to distinguish the appropriate zone where the fault has occurred. This may cause mal-operation of protection for faults outside its zone. The impedance introduced by the Series Compensator will also cause inaccurate fault location when using conventional fault location algorithms (FLA). As a result, in recent years a number of improved protection systems and FLAs have been developed specifically for Series Compensated lines. Most these algorithms are impedance based and require line parameters. Thus the main aim of this project is to develop a settings free numerical algorithm that does not require any line parameters. This algorithm is required to be based on the Synchronised Measurement Technology (SMT). This technology uses synchronised voltage and current samples from both terminals of the line. This algorithm is later required to be validated using Real Time Digital Simulator (RTDS) at the National Grid Power System Research Centre at the University of Manchester.

The expected benefits of this research are:

- **Numerical algorithm for asynchronous distance protection of series compensated transmission lines (SCTL)**
- **Fault location algorithm for fixed SCTL using SMT**
- **Fault location algorithm for thyristor controlled SCTL using SMT**
- **Asynchronous fault location algorithm for fixed SCTL using SMT.**

Given the facilities at the University of Manchester and current progress, the potential for achieving the expected benefits is high. It is very likely that these benefits are realised.

Progress in the period April 2012 – March 2013

A new complete Fault Location Algorithm has been developed which does not require the use of any line parameters and is capable of locating faults for various types of symmetrical and asymmetrical faults has been developed. It can be used for both traditional as well as series compensated transmission lines. Over this period of time, the algorithm has been programmed and validated using data obtained from EMTP simulations. The algorithm has been simplified using a Newton Rhapson approach which is easier to implement. This version of the fault location algorithm has also been programmed and similarly validated. A shunt admittance effect compensation method to improve accuracies of fault location algorithms using two ended current and voltage data has also been developed programmed and tested.

Two conference papers and one journal paper have been published and another conference paper has been accepted to be presented in the Best Papers Forum for the 2013 IEEE General Meeting:

- **Z.Radojević, V.Terzija, G.Preston, S.Padmanabhan, D.Novosel, "Smart Overhead Lines Autoreclosure Algorithm based on Detailed Fault Analysis", IEEE Transactions on Smart Grids, vol.5 (accepted)**
- **S.Padmanabhan, V.Terzija, "New parameter-free fault location algorithm for transmission lines in phasor domain", *Proc. 2012 IEEE Power and Energy Society General Meeting,* pp.1-6, 22-26 July 2012**
- **S.Padmanabhan, V.Terzija, "Settings-Free Method to Account for Shunt Admittance in Fault Location", *Proc.2012 3rd IEEE Power and Energy Society Smart Grid Technologies Europe,* pp.1-7, 14-17 October 2012**
- **S.Padmanabhan, V.Terzija, "Line parameter-free fault location algorithm for Series Compensated Lines", *2013 IEEE Power and Energy Society General Meeting,* pp.1-5, 21-25 July 2013 *(*selected as one of the best papers submitted for the conference and is to be presented at the best papers forum session)**

Influence of oil contamination on the electrical performance of power transformers (Shekhar Mahmud, Southampton)

In the present proposed project, we intend to extend our initial work to consider both metallic and insulating particles under both dc and ac voltages. This is extremely important to power converter transformers which are one of the key components in high voltage dc transmission systems. Power converter transformers experience the combination of dc and ac voltages during operation.

To fully understand the characteristics of contaminants under the combined dc and ac voltage, bridging characteristics under dc and ac voltage will be studied separately. In addition to live optical observation and capturing of bridging phenomena between two spherical electrodes in oil under different voltages, contamination levels and oil and paper insulation conditions, electrical conduction currents and partial discharges will also be measured simultaneously during bridging. Finally, the electric breakdown tests of these various contaminated oils will be carried out.

To simulate extreme cases of non-uniform electric field and its influence on pre-breakdown characteristics of contaminated transformer oil, a needle-plane electrode system will be further investigated. Similar tests to the two spherical electrodes outlined in the above section can be performed.

As the project develops forward, practical application will be considered such as the effects of electrode and temperature. The influence of coated/wrapped electrode on bridging dynamics can be explored. As transformers are typically operated at elevated temperatures, therefore, it is vital to extend the above research to a higher temperature regime. Particle bridging characteristics as a function of oil viscosity will be revealed as oil viscosity changes with temperature. The comprehensive experimental results will allow us to establish a good understanding of contamination and its relation to electrical performance and pre-breakdown phenomena.

To aid the understanding of bridging dynamics in the contaminated oil, a numerical model of particle movements and their accumulation at high field regions will be developed. It will be based on the hydrodynamic drift-diffusion approximation for the particles' motion under dielectrophoresis (DEP) forces. Additionally, the effect of particles shape and surface roughness on dust migration will be studied and an average (and easy measurable) parameters to characterise a wide variety of dust particles will be found from the simulation. This will create a link between the simulation and the practice, plus provide a verification tool for the model. The model assumptions will be tested by experiments with variety of dust particle (bunches of different sizes and shapes).

By assigning appropriate conductivity values to the oil and contaminant, it is

possible to obtain the current that flows during the bridging. It will be compared with the electrical conduction current measured under various conditions. Furthermore particles' percolation as a function of particles geometry and volume fraction will be modelled and the effects of dust accumulation around the electrodes on breakdown initiation will be understood.

This step by step approach will provide us with essential knowledge of oil contamination on the electrical performance of power transformers so that a set of criteria about oil contamination levels can be established to reduce potential transformer failures in power systems.

The student will be involved in comprehensive experimental work and computer simulation. This will equip the student with a broad range of skills and knowledge for future carrier in either industrial or the academic world. In addition to research specific skills training, the school involved in this project has a large and well-established postgraduate school offering a wide range of (compulsory and optional) courses covering subject specific and generic skills, as well as exciting seminar programmes. The student will have regular opportunity for scientific discussion, problem solving and presentation of the work at meetings with the industrial partner and at international conferences. Written skills and report writing are enhanced through the monthly report system, which includes presentation of experimental details and recorded data.

The University has a well equipped High Voltage Laboratory to carry out all the experiments for this project. All the necessary software for this project is also provided.

Progress in the period April 2012 – March 2013 has been:

1. **Bridging experiments with four different sizes of cellulose particles contaminated transformer oil have been carried out under the influence of three different DC voltages. Each particle category was tested with three contamination levels.**
2. **Experiments of cellulose particles with several contamination levels under the influence of AC electric field have been carried out.**
3. **Experiments of transformer oil contaminated with cellulose particles under the influence of DC biased AC electric field have been carried out.**
4. **Investigation of cellulose particles contaminated transformer oil under the influence of DC, AC and DC biased AC voltages have been carried out with Needle – Plane electrode system.**
5. **Partial discharge measurements cellulose particle contaminated transformer oil also accomplished with bare spherical electrode system and needle – plane electrode system.**
6. **Experiments have been carried out with transformer oil contaminated by cellulose particle under the influence of several levels of DC electric field with spherical electrode covered with craft paper.**

A report was produced for National Grid after completion of first year (January 2012). Another report will be delivered soon after the MPhil to PhD transfer in May 2013.

Conference Papers:

- ***Mahmud, S, Chen, G, Golosnoy, I O, Wilson, G and Jarman, P (2012) Experimental Investigation on Bridge Formation in Contaminated Transformer Oil. In, The Fifth UHVnet Colloquium, University of Leicester, Leicester, UK, 18 - 19 Jan 2012. , 10. (Published)***
- ***Mahmud, S, Golosnoy, I O, Chen, G, Wilson, G and Jarman, P (2012) Mathematical Modelling on Bridge Formation in Contaminated Transformer Oil. In, The Fifth UHVnet Colloquium, University of Leicester, Leicester, UK, 18 - 19 Jan 2012. , 35. (Published)***

- *Mahmud, S., Golosnoy, I.O., Chen, G., Wilson, G. and Jarman, P. (2012) [Numerical simulations of bridging phenomena in contaminated transformer oil.](#) In, 2012 IEEE Conference on Electrical Insulation and Dielectric Phenomena, Montreal, Canada, 14 - 17 Oct 2012. 4pp, 383-386. (Published)*
- *Mahmud, Skekhar, Chen, George, Golosnoy, Igor O., Wilson, George and Jarman, Paul (2012)[Bridging phenomenon in contaminated transformer oil.](#) In, Proceedings of 2012 International Conference on Condition Monitoring and Diagnosis. 2012 International Conference on Condition Monitoring and Diagnosis Piscataway, US, Institute of Electrical and Electronics Engineers, 180-183. (Published)*
- *Mahmud, Skekhar, Chen, George, Golosnoy, Igor O., Wilson, George and Jarman, Paul (2013) Bridging in contaminated transformer oil under DC and AC electric field. In, Dielectrics 2013, Organised By the Institute of Physics Dielectrics Group, University of Reading, Reading, UK,10 – 12 April 2013.(Awaiting to submit full paper)*

Reducing the Risk of Sub-Synchronous Resonance in Meshed Power Networks with Increased Power Transfer Capabilities. (Atia Adrees, Manchester)

Following the first two reported shaft failures in Mohave power station (USA) in 1970 and 1971 due to torsional oscillations, a number of studies have been carried out to explain the phenomenon and to propose countermeasures. Torsional (mechanical torques) oscillations are usually associated with sub-synchronous resonance phenomenon. Undesirable sub-synchronous oscillations that may lead to SSR (sub-synchronous resonance) and significant increase in mechanical torques, can arise in general in any compensated or uncompensated power system when natural frequency (f_{m0}) of mechanical system is very close or equal to the complement (f_c=50-f_0) of the natural frequency (f_0) of the electrical system. The potential sources of sub-synchronous oscillations can be classified into three categories.

i. **Series capacitance compensation of network**
ii. **Interactions with series compensators**
iii. **Interactions with HVDC controllers**

It is anticipated that in order to increase power transfer between critical areas and accommodate new generation (mainly offshore wind) without building new AC transmission lines, future Great Britain power network and other power networks around the world could include multiple series compensated lines and HVDC lines. These types of lines give rise to SSR under certain conditions. There have been studies related to control of SSR in networks with compensated transmission lines with FACTS devices and very a few with HVDC lines. The SSR phenomenon in meshed power network with multiple, relatively short, series compensated AC lines and HVDC lines operating separately or in parallel as GB transmission network could look in near future has not been investigated in the past at all.

The objective of this research is to explore in detail, scenarios which can lead to SSR in meshed power networks with relatively short but heavily compensated AC transmission lines operating in parallel with HVDC lines and to propose, using probabilistic risk based index, adequate AC/HVDC topologies that minimise the exposure to SSR.

Expected benefits of this research are summarised below

- **Clarify significance of SSR studies for future networks considering that type and size of energy generation will change leading to significant changes in transmission network.**

- **Provide quantitative and qualitative comparison among different transmission network structures with respect to avoidance of SSR.**
- **Small and large disturbance studies carried out during this research, under various operating scenarios including multiple uncertainties in electrical and mechanical system parameters will help to establish robustness of different compensation and power transfer technology options and to identify safe operating ranges for each of the feasible solution.**

Contribute towards the growing research work to meet carbon reduction target of 2020 (EU renewable energy directive) and 2050 vision for UK power systems.

Significant progress in the work has been made to date and objectives of this research are realistic. It is expected that all objectives of this research will be fully achieved and benefits will be realised.

Progress in the period April 2012 – March 2013 has been

- **Two indices, one for torsional interactions and one for transient torques amplification, are developed to quantify the problem of SSR. Generators in a large network are ranked based on the severity of SSR problem using these indices and results are verified using electromagnetic transient simulations.**
- **A methodology for the risk evaluation of SSR is also developed. This methodology can identify the levels of SSR risk, the generators in the network are exposed to, in each contingency considering the probability and severity of SSR problem.**
- **The influence VSC HVDC system operating parallel to compensated lines in a large meshed network is also investigated. Studies are performed with different power transfers through the VSC link in various network configurations.**

Journal Papers:

- ***J.V.Milanovic and Atia Adrees, "Identifying Generators at Risk of SSR in Meshed Compensated AC/DC Power Networks," submitted to IEEE Transactions on Power Systems, TPWRS-01340-2012***
- ***Atia Adrees and J.V.Milanovic, " Methodology for Evaluation of Risk of Subsynchronous Resonance in Meshed Networks" submitted to IEEE Transactions on Power Systems, TPWRS-00349-2013***

Conference Papers

- ***A.Adrees and J.V.Milanovic, "Subsynchronous Resonance in Meshed Networks with HVDC lines," in Proc.2nd IEEE PES International Conference and Exhibition on Innovative and Smart Grid Technologies (ISGT Europe), Manchester, UK, December 2011, pp.1-8.***
- ***A.Adrees and J.V.Milanovic, "Effects of Uncertainties in shaft mechanical parameters on maximum torsional torques in meshed networks with HVDC lines," in Proc .IEEE PES Transmission and Distribution Conference and Exposition (T&D), Orlando, Fl, USA, May 2012, pp.1-8.***
- ***A.Adrees and J.V.Milanovic," The Effects of Uncertainty in Mechnical Parameters on SSR in Meshed Power Networks with Different HVDC Technologie,"in proc. 12th International Conference on Probabilistic Methods Applied to Power Systems(PMAPS), Istanbul, Turkey, June 2012,pp 1-8. – award for the best student paper at the conference***
- ***A.Adrees and J.V.Milanovic, "Index for Ranking Generators Based on Risk of Subsynchronous Resonance in the Network," accepted for the IEEE PowerTech Conference, Grenoble PowerTech 2013, June 2013, Grenoble, France.***
- ***A.Adrees and J.V.Milanovic, " Study of Subsynchronous Resonance in Meshed Compensated AC/DC network," abstract accepted for IREP***

Symposium 2013, August 2013, Crete, Greece.

Effect of Climate Change on Design and Operation of Meshed Networks (Kirsty Murray, Strathclyde)

The GB power network suffers from regular faults with a percentage of them caused by adverse weather. With the current worry about climate change and the possibility of increased and less predictable adverse weather there is a concern that this will affect the reliability of the network. The Met Office's Hadley Centre has just completed work for GB operators on the risk of climate change effects on the network, thus allowing network operators the chance to change their design standards or make adjustments to the way they run the network.

The Met Office's work mainly looked at the distribution network due to the difficulty of quantifying the impact on the transmission network. This is much harder to measure on the transmission network due to the way that it's designed and operated i.e. in a meshed fashion with a higher redundancy. This means that faults on the transmission network that cause a loss of supply are classed as low probability but high impact, they can lead to long restoration times and blackouts and therefore should not be ignored.

The aim of this project is to assess the risk of disturbances on the transmission network due to weather and to draw a comparison between today's weather effects and future weather effects after climate change

The expected benefits of this research are:

- **To provide the transmission operators the chance to see how adverse weather affects the transmission network and how the effect of climate change (more adverse weather or different types) will affect the networks in the future.**
- **Allow the operators to plan and manage the system more effectively**
- **Allow them to look at the suitability of network design and allow relaxation of network security when certain weather types are forecast**

It is likely that the benefits of this project will be achieved in conjunction with the three transmission companies with the provision of their data in an adequate volume for simulations in order to provide realistic results.

Progress in the period April 2012 – March 2013 has been

- **A large amount of reading has been completed to give a good base of understanding for what work has previously been undertaken in similar areas and is on going**
- **The Value of Security Assessor (VaSA) code, which will be used to run the simulations, has been acquired. Consists of a Monte Carlo simulation and load flow analysis**
- **Research into simple statistical methods has being undertaken and they have been applied to the data**
- **Past weather data was collected for the years 2010 and 2011 to allow weather fault data from National Grid to be assigned a weather category**
- **Fault data has been collected from National Grid (1996-2011), all years have been extracted in to a separate workbook under weather categories and initial analysis has been carried out. National Grid was also split into four sub-regions to allow further analysis**
- **Fault data has been collected from SSE (1986-2012) and all weather faults have been extracted in to a separate workbook under weather categories and initial analysis has been carried out**
- **Fault data has been collected from SP (1984-2012) and all weather faults**

have been extracted in to a separate workbook under weather categories and initial analysis has been carried out
- Non-weather faults for all three companies has been complied together to allow comparison between weather and non-weather faults
- Further analysis has been carried out on both weather and non-weather faults, looking at the number of faults per year per km/equipment
- MATLAB was used to create a distribution based on given return to service (RTS) times and used to filled in the blank RTS times
- British Atmospheric Data Centre (BADC) past weather data from 1984-2012 has been downloaded and ERA-Interim reanalysis past weather data has also been looked at in order to create relationships between weather and weather related faults
- Received substation location data from the three transmission companies once turned into latitude and longitude it will help complete the next stages of work
- Research into future emission scenarios has also been undertaken and will now look at future climate scenarios
- Research into fault reporting in the UK and other countries is being undertaken
- Attended Optimisation and simulation methods for large power systems course in Athens
- Attended and passed EE973 Advanced Power System Analysis and Protection
- Passed University First Year review
- Presented a poster at Renewables and the Future of Energy Meteorology (17^{th} October 2012, Imperial College, Royal Meteorological Society).

Progress report submitted to National Grid and abstract submitted to CIGRE 2014.

Influence of wind uncertainty on National Grid's Operating Reserve (Karl Hartwig, University of Strathclyde)

In order to meet emission reduction targets, the GB power system will need to incorporate renewable sources and these will affect system operation in a number of ways. One of the significant changes is related to the provision of the system operating reserve, which defines the ability to adjust generator or demand to manage differences between actual and forecasted demand, as well actual and planned generation. In order to secure sufficient flexibility National Grid which acts as the UK system operator has defined a Short Term Operating Reserve Requirement (STORTT), which defines the level of reserve needed at four hours ahead to meet specified security requirements.

This project will seek to address main issues raised in the National Grid 2020 consultation document ["Operating the Electricity Transmission Networks in 2020", available at www.nationalgrid.com/uk/Electricity/Operating+in+2020] regarding the intention to address procurement and planning of reserve in the Future Reserve Review. Two main topics of the Review are considered to be:
i. Improvement of existing reserve services provision
ii. Long-Term Reserve Development

The output of this project will include a set of recommendations and definitions for technical requirement for reserve provision, as well as new tools that will help National Grid evaluate influences of changes in future system operation due to integration of different generation technologies, demand response as well as

	uncertainness that these changes will bring. These new recommendations and tools will seek to help National Grid optimize reserve provision so that it can facilitate integration of renewable to improve environmental and operational benefits. In addition, by optimizing for reserve planning National Grid will also seek to achieve least cost system operation while maintaining secure system operation. **Progress in the period April 2012 – March 2013 has been:** • **A review of the published literature within the fields of wind power forecasting and integration, power system reliability as well as stochastic and linear programming has been conducted.** • **This has formed the foundation for the development of stochastic programming models that combine generator dispatch and energy trading analysis. Some models are currently under development and the aim is to refine these to investigate methods of improving procurement of power system reserve within the UK.** • **Two visits have been made to the industrial partner, of which one was a one week long. During these visits refinements of the project aim was discussed. This has resulted in the current direction of the research.** • **Other activities conducted involves a poster presentation at the Power Network Research Academy on 4 December 2012 as well as attendance at "The risk and reliability modelling in power systems" day at Durham University on 27 November 2012** **The following objective will be completed within the next six months;** • **Create a solid understanding of stochastic processes and stochastic programming,** • **Produce a stochastic unit commitment program,** • **Apply the above mentioned program to a simple test system to identify the influence of wind forecast errors on dispatch decisions (slow vs. fast units, spinning vs. non-spinning reserve).** • **Complete a report of the published literature related to decision making under uncertainty in power system, current development within wind forecasting tools as well as applications of stochastic programming to power systems.**
Collaborative partners	**PNRA: EPSRC, National Grid, Scottish and Southern, Central Networks & EDF Energy Networks.**
R&D providers	**PNRA: Universities of Cardiff, Manchester, Queens (Belfast), Southampton, Strathclyde, and Imperial College London.**

Project title	Resilient Electricity Networks for Great Britain (RESNET)		
Project Engineer	Doug Dodds		
Description of project	The RESNET project is funded by EPSRC to allow researchers from the University of Manchester and the University of Newcastle to examine the future resilience of the UK electricity network to climate change. The resilience of the UK electricity network is being addressed on three fronts: (i) Representation of changed performance of network components under future climatic conditions (operational resilience), using reported datasets and models to construct performance curves of the system components under a range of climatic conditions (e.g. transmission line capacity for given ambient temperature). To represent the range of performance for each component type, and capture uncertainties in data, these will be presented as probability density functions. (ii) Risk of failure modelling of components under extreme weather events (infrastructure resilience): Fragility functions will be developed to describe failure of energy infrastructure from weather related phenomena (e.g. probability of transmission tower collapse as a function of wind speed). Relevant loading variables will be specified for each element and fragility functions subsequently established by (i) literature review and analysis of past events (e.g. failure patterns during the 1987 storm) (ii) interaction with stakeholder partners and (iii) finite element analysis of selected components. (iii) Whole system modelling: To develop quantitative estimates of the effect of climate change on the day-to-day performance of the electricity grid, first using the existing National Grid and one or more existing distribution network before analysing scenarios and adaptations from other work packages. Monte Carlo simulations will be used for each case with the difference in performance of the system between the base case and the modified cases measured using the following criteria: Increase in operating cost required to maintain the standard level of service; Quantified demand response or load shedding needed to maintain service; Probability of customer outages and expected energy not served; Quantity of renewable energy spilled. To address this dual challenge, the project will see the development of a comprehensive approach to analyse, at the UK scale, the resilience of the electricity network and the development of tools for testing adaptation measures that enhance the resilience of the network. The project will explore adaptations at a broad spatial scale and over extended timescales (2020, 2050 and 2080).		
Expenditure for financial year 11/12	Internal £5k External £56k Total £61k	Expenditure in previous (IFI) financial years	Internal £3k External £31k Total £35k
Total project costs (collaborative + external + [company])	£96k	Projected 2013/14 costs	£52k

Technological area and/or issue addressed by project	National Grid has previously completed work on the weather related risks to National Grid and how they may increase/ decrease with time. This work is investigating the electrical system's ability to cope with the changes that climate change will have on the electricity transmission system. This work not only aims to incorporate the change in climate but also the change in supply and demand, which is predicted, with changing climate and a growing population. The proposal also states that it will model the network on a nodal basis to enable an investigation of the entire system. This project is a result of an EPRSC research call on Climate change and was awarded to the University of Manchester and the University of Newcastle. It combines the system knowledge of Manchester Electrical Engineering department with the Tyndale Centre, a leading centre on Climate change, with Newcastle University's expertise in weather systems and structural knowledge.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		4	0	4
Expected benefits of project	This work will have impact on National Grid's strategies with respect to climate change or extreme events. This work will assist National Grid's ability to mitigate the risk related to climate change, while both investigating the changes in demand due to climate change and the effects that this loading, coupled with changing external environment, will have on the electrical equipment that exists on the current network. This is vital for National Grid to maintain its reputation and security of supply to the country. Full benefits are not know at this time however there is potential cost avoidance if it is proved that the electrical equipment on the system can withstand the changes that may occur due to climate change. The project engineer will seek quantified benefits from project board as the project delivers knowledge, and ensure that the Climate Change Policy/Adaptation team be kept aware of project.			
Expected timescale of project	4 years	Duration of benefit once achieved	8 years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£137k	
Potential for achieving expected benefits	Benefits will be achieved through delivery of the objectives, made more likely by National Grid's good working relationship with the University of Manchester. The Tyndale Centre and Newcastle University are leaders in the fields that they are bringing to the project. That said the likelihood of success is medium as there are many variables that are being included in this project and the scope of work is far reaching.			

Project progress [Year to End of March 2013]	**Fault statistics data and knowledge has been shared with Sean Wilkinson of Newcastle University. Stakeholder workshops covering energy forecasting, line rating and National Grid's 2020 operational vision resulted in a rethink on some aspects of the RESNET project including some aspects of National Grid adaption risk report from Cranfield University.** **A report on the impact of climate change on system ratings has been issued and received by National Grid with technical transformer experts providing feedback and detailed comments on the contents back to the University of Manchester.**
Collaborative partners	
R&D provider	**University of Manchester, Newcastle University**

Project title	Electric and Magnetic Fields and Health			
Project Engineer	David Renew			
Description of project	The possibility that there may be effects of electric and magnetic fields (EMFs) on health is an important issue for National Grid. This project will enable National Grid to strengthen its understanding in the face of the external threat of the EMF issue, through helping it to avoid unjustified constraints in its operations while at the same time ensuring that the EMFs associated with the operations are not the cause of any adverse health effects. This is an umbrella project providing resource for a variety of aspects of research on EMFs and Health, including resource directed towards management of projects funded elsewhere.			
Expenditure for financial year	Internal £83k External £188k Total £271k	Expenditure in previous (IFI) financial years	Internal £211k External £2,622k Total £2,833k	
Total project costs (collaborative + external + [company])	£9,318k	Projected Costs 13/14	£493k	
Technological area and/or issue addressed by project	This project addresses interaction of electric fields and magnetic fields with people, and the assessment of fields associated with the use of electricity.			
Type(s) of innovation involved	Significant	Project Benefits Rating 11	Project Residual Risk 2	Overall Project Score 9
Expected benefits of project	While there is not likely to be a direct financial gain from this long-term research, without it there may be considerable additional costs and constraints imposed on the electricity industry operations arising from lengthy and costly debates about EMF and from unwarranted exposure limits or other constraints on operations. For example an assessment provided to the then DTI about the possible cost to National Grid of implementing the EU Recommendation (1999) on public exposure to EMFs included estimates of up to £850M. Another assessment, to the HSE, about the cost to National Grid of implementing an previous version of the EU Directive on occupational exposure to EMF identified costs of the order £10-100M per year. In 2005, the assessment published by the Stakeholder Advisory Group on EMFs estimated compensation costs payable by National Grid to landowners if an EMF risk because established as potentially several hundred Millions of £.			
Expected timescale of project	Ongoing	Duration of benefit once achieved	Years: Indefinite	

Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£2,500k**
Potential for achieving expected benefits	**The EMF issue has existed for many years, and so has funding of research in this area by National Grid and its predecessors. It is clear that this funding has made real difference in both the lay and scientific arenas – for example the conclusion of the WHO Environmental Health Criteria which focus on childhood leukaemia as opposed to other widespread health outcomes such as breast cancer. Nevertheless the issue is so broad and continuously developing that continued efforts will be needed for the foreseeable future.**		
Project progress [Year to End of March 2013]	**The multiple strands of this long-term project progress at different rates, leading towards publication in the scientific literature.** **EPRI research funded from this project** **The Electical Power Research Institute (EPRI) in the USA conducts EMF research which is funded by National Grid among many other electricity industry companies. They have continued to seek answers to questions surrounding childhood leukaemia and magnetic field exposure and related issues. EPRI research submitted for publication in the peer review literature includes: magnetic fields in electric vehicles; studies on smart meter radio frequency (RF) emissions; international study of magnetic field exposure and survival from childhood acute lymphoblastic leukaemia; influence of conditions at birth on the risk of childhood leukaemia.** **EPRI reports have also been produced on many topics including: the impact of stray voltage and on dairy cow health and milk production; causes of power system distortions, harmonics, and noise; the interaction between AM radio broadcast antennas and overhead power lines; environmental and potential health effects of HVDC transmission lines.** **A number of EPRI reports focused on RF EMFs: review of RF emissions from consumer wireless electronic devices; EMF and RF measurements at solar generation facilities and residences with solar panels; an evaluation of RF exposure meters; a brief providing background information on RF exposure in human laboratory studies.** **In addition EPRI software for calculating RF fields (RF Estimator 2.0) and extremely low frequency (ELF) fields (EMF Workstation 2012) were released and three workshops were held and reported on: research progress of the TransExpo study; evaluation of electromagnetic iInterference with medical devices in the workplace; EMF and aquatic life.** **Other research funded from this project** **A preliminary study of possible interference of power lines with precision agriculture Global Positioning System (GPS) systems has been completed.** **A study of specific electric field screening structures for control of microshocks was completed.** **Preparations are being for an initial computational study of induced electric field in the body in uniform electric and magnetic field.** **Preparations are continuing to be made to provide funding for a study in London Ontario of the thresholds for magnetic field stimulation of magneto phosphenes which is relevant to exposure limit legislation.** **Other resources obtained relate to EMF news updates, and literature,**		

	software and instrumentation. **Other EMF research – funded separately from this project** **The EMF Biological Research Trust, funded by National Grid (but not as part of IFI for 4/11 to 3/15), and managed independently, is a program of research into biological effects of magnetic field. Their projects are all published in the peer review literature. They have eight "current" projects three of which started during the year to March 2012. Three are at Oxford University (Evaluation of sleep associated behaviours in response to low frequency magnetic fields, 3 years), the University of Manchester (Transient radicals: carriers of magnetic field -sensitivity on humans, 3 years), and University of Oxford Department of Chemistry (Magnetic field effects on cryptochromes, 4 years).** **National Grid also contributes to the wider electricity industry research on EMFs and, although this strand is not within IFI, it is run as a single integrated programme by the Energy Networks Association. This includes ongoing work on the health of electricity industry employees, using the database of staff created in the 1970s, which continues to provide reassuring results and mortality from cancer, and more recently also incidence of cancer. Two papers have been submitted for publication in the peer review literature of association between occupational exposure to magnetic fields to leukaemia and to brain cancer, which are repeats of previous similar studies, but including more recent incidence data and more recent mortality data so that they have larger numbers of subjects. A study of adult cancer in proximity to high voltage power lines has been published in the peer review literature.**
Collaborative partners	**Energy Networks Association, Department of Health, EPRI.** **Children with Leukaemia, Childhood Cancer Research Group, EMF Biological Research Trust (some of these partners are involved in the components of the research programme which do not come under IFI).**
R&D providers	**Resource Strategies Inc, the University of Manchester, EMF Biological Research Trust and others via collaborative partners including HPA-RPD, UCLA, Microwave Consultants Ltd, SAHSU, Institute of Occupational and Environmental Medicine (University of Birmingham). Some of these providers are involved in the components of the research programme which do not come under IFI.**

Project title	Effective Protective Coatings for OHL Towers			
Project Engineer	David Clutterbuck			
Description of project	A number of tests have been carried out by EA Technology on behalf of a group of electricity supply industry (ESI) companies. This includes the evaluation of a number of new products and special purpose paint systems. Inspections of trial towers painted with a newly developed environmentally friendly water based system have also been carried out. National Grid has requested the opportunity to participate in the final stages of the testing. Participation will ensure access to all test results to date and the final report when complete.			
Expenditure for financial year	Internal £5k External £7k Total £85k	Expenditure in previous (IFI) financial years	Internal £32k External £33k Total £65k	
Total project costs (collaborative + external + [company])	£209k	Projected 2013/14 costs for National Grid	£9k	
Technological area and/or issue addressed by project	Impending European legislation may restrict further the use of high Volatile organic compounds (VOC) paints for any industrial use. The only approved National Grid tower paint product falls into this category. Maintenance policy requires the painting of approximately 1200 towers per year. Predicated ongoing spend on tower painting is £6.85 million per year, hence requirements have been identified for continued research to test and evaluate the performance of alterative paint products to ensure the company is prepared for any changes to legislation.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		9	0	9
Expected benefits of project	The expected benefits of undertaking this research are as follows. Compliance with European Law regarding VOC emissions. Reduction to single coat paint systems (two coats currently used). Reduction of steelwork replacement during overhead line (OHL) refurbishments. Optimised Asset Management approach for managed paint maintenance. Improved algae removal solution.			
Expected timescale of project	5 Years	Duration of benefit once achieved	5 Years	

Probability of success	**80 %**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£3,048k**
Potential for achieving expected benefits	**The original alternative epoxy paint proposed has proved problematic and not fully effective during field trials, however significant progress has been made with alternative low VOC and water based coatings. The alternative coatings being tested show good potential for meeting both VOC compliance and performance. The new products are still improving but are already being introduced ahead of European legislation changes.**		
Project progress [Year to End of March 2013]	**Development of improved single coat paint solutions. Interest from additional suppliers for supply of paint systems, HMG paints and Pronto industrial coatings have been engaged with producing systems that could meet our specifications. Carrying out audits on these 2 suppliers. A number of paint systems have been tested and discounted. For non-corroded steelwork a single coat is proving effective while for corroded steel, enhanced preparation and a 4 coat patch system is being tested. 4 coat patch system has been developed and is being trialled. Development of a more cost efficient paint system for tower concrete muffs. Presently a bituminous coating is applied which generally lasts 3 years and requires frequent visits to the tower to re-apply. We intend to develop a system which has a comparable cost to bitumen but will last for 18yrs (which will coincide with the tower painting maintenance frequency). Algae issue. Due to increasing problems with algae on towers we are looking into systems to combat this. ENA 43-90 legislation change. This document has been amended and in the appropriate circumstances some towers will no longer be required to have anti climbing barbed wire. An alternative means of deterrent such as anti-climbing paint could be used which will need to be developed.**		
Collaborative partners	**United Utilities, Scottish Power, CE Electric UK (NEDL), Scottish and Southern Energy, Central Networks, EdF Energy**		
R&D provider	**EA Technology**		

Project title	Voltage transducers for power quality measurements		
Project Engineer	Forooz Ghassemi		
Description of project	The aims of this proposal are : To devise test procedures for determining high voltage (HV) and extra high voltage (EHV) voltage transducer frequency response. This can be incorporated in international standards such as IEC. To determine frequency characteristic of typical wound voltage transformers (WVTs) in National Grid's network and hence assess the accuracy of the historical data. To examine the frequency response of residual current devices (RCDs). To examine the use of capacitor voltage transformers (CVTs) for power quality measurements by considering the use of a new add-on device, the PQSensor, to a standard CVT. The device response and capability would be examined. Key Deliverables 1: Specification for source, test rig and procedure (4 months) 2: Design, build and commissioning of source and test (12 months) 3: Specification for reference measurement system. (1 months) 4: Design and build of reference measurement system (4 months) 5: Review and update of test specification (2 months) 6: Review and update of specification for reference measurement system (1 months) 7: Test on different type of WVTs (2 months) 8: Test on different type of RCDs (2 months) 9: Test on CVTs with new sensors. (2 months) 10: Analysis of data and reporting (6 months)		
Expenditure for financial year	Internal £4k External £0k Total £4k	Expenditure in previous (IFI) financial years	Internal £25k External £207k Total £232k
Total project costs (collaborative + external + [company])	£236k	Projected 2013/14 costs for National Grid	£0
Technological area and/or issue addressed by project	To assess the suitability and accuracy of voltage transducers for power quality and wide band measurement.		

Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		6	-1	7

Expected benefits of project	This project will result in a saving of almost £500k considering just wind farm connections and HVDC schemes planned. 1. WVTs have been used by National Grid as the acceptable transducer for power quality measurements. This is because of their wider bandwidth. 2. Power quality measurements are limited to sites with WVTs, which are not available at all substations because of their costs and size. 3. When considered for substations, due to their costs and space requirements, only a single unit has been used usually connected to the yellow phase. 4. Accuracy of measurements taken so far and are being taken through WVTs are not known. Recent comparative measurements have indicated discrepancies in measurements even at low order harmonics. 5. WVTs are expensive and not being used as standard transducers in schemes. They have to be specified on a project by project basis. 6. RCDs are required to be specified in schemes related to tractions, HVDC and other polluting loads. 7. RCDs must be used in parallel with CVTs, nearly doubling the cost of the installation. 8. WVTs and RCDs require additional substation space. 9. Instead of WVTs or RCDs, CVTs together with new accessory, the PQSensor, can be used in power quality monitoring, which in turn will reduce cost and save space, outage time and civil work. 10. PQSensor can be ordered with the new CVTs or retrofitted to the in-service units. 11. CVT and its add-on also make it possible to carry out power quality monitoring at all substations as CVTs are present in all EHV substations. 12. IEC standards for instrument transformers need to be reviewed with respect to power quality requirements. There is no reference to power quality measurement capability in present IEC standards. 13. At National Grid, a new policy paper for monitoring requirement is in preparation. The project's results will help to incorporate voltage transducer requirements into the paper. 14. The project outcome should show that the cost of voltage transducers can be reduced in schemes.

Expected timescale of project	3 years	Duration of benefit once achieved	6 years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£47k

Potential for achieving expected benefits	**The project is slightly behind due to a delay in finding a suitable reference transducer and difficulty in design of isolation between high voltage 50Hz and harmonic sources.** **The project is getting back on track and should achieve the benefits.**
Project progress [Year to End of March 2013]	**- Two 400kV (230kV ph-N) instrument transformers have been tested at the fundamental frequency component of 210kV plus superimposed harmonics up to 5 kHz.. This is the first of its kind in the UK or possibly the world.** **- This test rig has been initially designed to test any instrument transformer with low capacitive input impedance.** **- RCDs could not be purchased due to long delay time by manufacturer.** **- A 400kV CVT has been tested.** **- A smaller version of the same design was initially designed and set up for instrument transformers up to 33kV. 11kV and 33kV instrument transformers have been tested.** **- The test system is semi-automatic and signal generation and control are performed in a computer.**
Collaborative partners	**University of Manchester**
R&D provider	**Areva, ABB , University of Manchester**

Project title	Future Real Time Demand Forecasting		
Project Engineer	Alex Carter		
Description of project	This project will produce a flexible computer model of current and future electricity system demand for use in near term demand forecasting. It will first understand the current makeup of demand and will then introduce the impacts of expected changes in demand as decarbonisation drives changes in domestic demand. This model will enable different scenarios to be examined to understand the different influences on a range of developments such as heat pumps, electric vehicles, distributed generation and improved insulation and the consequential impact on final electricity demand. This will help to define what developments are needed to improve near term demand forecasting.		
Expenditure for financial year 11/12	Internal £6k External £0k Total £6k	Expenditure in previous (IFI) financial years	Internal £6k External £161k Total £167k
Total project costs (collaborative + external + [company])	£173k	Projected 2013/14 costs for National Grid	£0k
Technological area and/or issue addressed by project	Decarbonisation will change the demand that needs to be supplied from the electricity transmission system. Some examples are heat pumps, electric vehicles, distributed generation and improved insulation. Some of these will increase electricity demand whereas others will reduce it. Approximately 15GW of distributed generation is anticipated to be connected. National Grid therefore needs to understand the impact of different take up rates of these developments on the real time electricity demand and the uncertainties associated with them to ensure that we continue to be able to forecast demand accurately to operate securely and economically in to the future. National Grid currently forecasts maximum demand to an accuracy of approximately 1-2%. Decarbonisation to meet the EU and Government 2020 CO_2 emission targets will change the nature of electricity demand and potentially reduce the ability to forecast it accurately. Increasing amounts of intermittent generation being connected to the transmission system, 30GW by 2020, also means that demand at all times of the day becomes important and not just the historic evening peak. Accurate demand forecasting ensures that the correct amount of response and reserves are held to ensure that electricity is supplied securely and reliably, and at an economic cost that is ultimately borne by electricity consumers.		

Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		6	2	4

Expected benefits of project	**Under or over forecasting demand typically increases system operation costs, this is conservatively estimated to be 1 action per week costing ~£100k which this project would look to assist in removing through better demand forecasting.** **These actions are expensive because short term balancing actions are required on marginal plant such as hydro and open cycle gas turbines. A greater understanding of the different ways that demand may develop under different scenarios will ensure that appropriate mitigating changes can be made to our demand forecasting processes to prevent our forecasting accuracy decreasing and therefore significantly increasing our system operation costs.** **We are currently planning to spend approximately £4m on developing our forecasting capability between 2011 and 2020 and this project will contribute to ensuring that the developments are focussed in the right areas.** **Future work with the project partners could look at the impact of future energy saving measures on the balance between electricity and gas demand.**		
Expected timescale of project	**1 year**	**Duration of benefit once achieved**	**8 years**
Probability of success	**60%`**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£45k**
Potential for achieving expected benefits	**It is highly likely that the project will deliver the stated objective as the Energy Saving Trust, who will be delivering the project, are experts in understanding domestic energy use with extensive historic data and also have expertise in the industrial and commercial sector and also the expected impact of new technologies. They will be working with other expert partners as well as National Grid experts to understand the relevant issues.**		
Project progress [Year to End of March 2013]	**The Energy Saving Trust has delivered a beta version of their software that has been deployed at National Grid sites. This version is being tested by a group of National Grid experts to evaluate the validity of the forecasts being generated. The application provides forecasts at distribution and transmission level for eight archetype days in 2015 and 2020.** **The model allows the impact various low carbon technologies are expected to have on the within day demand to be investigated. The level of penetration from these is adjusted through sliders in the application or pre set scenarios can be used (e.g. Gone Green, Slow Progression etc.).** **The demand profile at the level of each distribution network operator or the National level can be exported from the application to spreadsheet based applications for further analysis.** **Comments on this version of the software will be returned to the Energy Saving Trust. Final documentation for full implementation of the project should be delivered in the next couple of months.** **One of the key features of this application that has proved of most interest is the use of propensity measures to predict how different consumers will behave in different parts of the country.**		

Collaborative partners	
R&D provider	**Energy Saving Trust**

Project title	Mathematics of Balancing Energy Networks Under Uncertainty			
Project Engineer	Iain McIntosh			
Description of project	The project will deliver mathematical models for uncertainty in energy networks and the management of this uncertainty through demand shifting and storage. It is hoped that it will help identify the value of storage technologies and thus understand the nature of the role they may be able to play in the future operation of the networks.			
Expenditure for financial year 12/13	Internal £4k External £8k Total £13k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k	
Total project costs (collaborative + external + [company])	£23k	Projected 2013/14 costs	£10k	
Technological area and/or issue addressed by project	Storage and demand shifting are regularly identified as a means of delivering the low carbon energy future of electricity by aligning availability of renewable resource (wind power) with demand. There are numerous potential storage technologies ranging from pumped storage, to batteries and thermal storage. Likewise, the concept of demand shifting is well understood, however the value to the industry and end consumer is not well understood. These are important questions to answer as the future balancing services for system operations are developed.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		2	-6	8
Expected benefits of project	The business benefit would be two fold. First it would help National Grid to articulate the value of storage and demand shifting strategies better to our customers and stakeholders and thus help shape both design of future services and a cost benefit of different products and technologies. The models would also include the ability to quantify the economic benefits of such new capabilities, to optimize their use, and to assess their impact on energy trading and markets. This should help us reduce operating costs, particularly in regards to operating margins and wind intermittency and assist in how we should target resources appropriately			
Expected timescale of project	5	Duration of benefit once achieved	8	
Probability of success	80%	Project NPV = (PV benefits – PV costs) x probability of success	-26985	

Potential for achieving expected benefits	**The chances of success are estimated to be very high. The student will work within a joint Heriot-Watt/Cambridge/Durham team, working on a major EPSRC project to develop the mathematics of storage, demand-shifting and the management of uncertainty in energy systems, together with its economic implications. This team includes the UK's leading mathematicians within this area and is further fully involved in international efforts to solve these problems. The student will be co-supervised at the Institute for Energy Systems at the University of Edinburgh, which is further heavily involved in efforts to solve these problems.**
Project progress **[Year to End of March 2013]**	**The student was not selected until October 2012 and then undertook six months of pre-project study and tutorials. The student commenced work on the project from March 2013.** **No results from the work are available or expected at this early stage.**
Collaborative partners	
R&D provider	**Herriot Watt University, University of Cambridge, University of Durham, University of Edinburgh**

Project title	Dynamic Ratings for improved Operational Performance (DROP)		
Project Engineer	David Payne		
Description of project	The project aims to investigate, develop and experimentally validate methods for the calculation of dynamic (real time) cable circuit ratings within the transmission network, to investigate potential deployment scenarios for such methods within the National Grid network and to determine the potential benefits of using such systems as the penetration of intermittent renewable generation grows within the network.		
Expenditure for financial year 11/12	Internal £4k External £111k Total £115k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£166k	Projected 2013/14 costs	£51k
Technological area and/or issue addressed by project	The installed length of cable circuits on the 400kV network has increased substantially in the last decade, particularly in London but also in rural areas where it is increasingly difficult to gain consent for the use of overhead lines. Cable circuits typically have a lower continuous current rating than overhead lines due to the increased thermal resistance between the cable and the ambient environment and as such can form the overall limiting factor on the amount of power which can be transferred through a given network link. Historically, National Grid has planned and purchased cable circuits based on the required continuous rating. Emergency ratings would then be calculated based on a set preload for a given time and would typically be applied in the event of a circuit outage elsewhere on the network. This approach provides a concise cable rating sheet as part of the CUP package which can be readily used by Network Operations. While this approach works well where the level of load to be transferred is known in advance, it provides for only a limited number of rating combinations based on a series of assumptions about the cable system thermal environment. Given the increasing variability of the UK climate, coupled with the trend towards higher generation of electrical energy from renewable sources, this may not always lead to the best utilisation of a cable asset as its true power transfer capability over periods of 24 hours or less may be under-estimated through this traditional approach. This study will investigate the development of dynamic rating algorithms applicable to a variety of common cable circuits through both numerical modelling, simulation and laboratory based experiments. The proposed work will be carried out within the Tony Davies High Voltage Laboratory at the University of Southampton. Principle targets for this study include: 1. The development and experimental verification of an algorithm for dynamic ratings applicable to buried cable circuits. 2. Further development of (1) for application to cables in air, for example troughs and tunnels. 3. The examination of possible integration of tunnel dynamic ratings with ventilation control options under investigation in the CCTV		

(Control of Cable Tunnel Ventilation) project.

4. Development of a framework detailing the data collection requirements and other pre-requisites for any future deployment of dynamic cable ratings within National Grid.
5. An analysis of the potential benefits of using dynamic ratings, particularly in terms of constraint cost reduction.

A four phase plan is proposed to investigate the target areas listed above, eventually leading to the derivation of a framework for how dynamic cable ratings could be utilised within National Grid and the associated costs and benefits of doing so.

Phase 1 requires the derivation of suitable algorithms to represent both the cable and the relatively unknown thermal environment. Previous cable ratings projects have examined transient cable models and hence some benchmarks already exist. Modelling of the cable environment is much more complex, involving a large range of parameters, some of which may not be clearly defined. As a result the project would investigate the development of both deterministic and statistical approaches for representing the cable environment, each of which may be more suitable depending on the cable installation. Seasonal conditions and trends would also become important; hence predictive techniques will be developed to account for expected future changes in the thermal behaviour of the cable environment based on recent operational and meteorological history. This is particularly important for cables installed in air, where changes in the ambient conditions have a much shorter time constant than would be the case for buried circuits. The principle installations considered, in increasing order of complexity, would be directly buried, filled and unfilled trough environments. It is considered likely that several different approaches would be developed and tested during phase one, ranging from relatively "conventional" ratings models based on the thermal network models used for static calculations through to more complex numerical tools which have seen success in areas such as partial discharge characterisation. This would allow comparison of the benefits of different modelling techniques, including those developed by other organisations (for instance EPRI).

Phase 2 would advance the study further to apply to forced-ventilation cable tunnel installations. These systems require a slightly different approach as some of the environmental parameters (such as air velocity) are actually controllable. The impact of such control inputs for a benchmark tunnel system are currently being investigated as part of the CCTV (Control of Cable Tunnel Ventilation) project between the University of Southampton and National Grid. This second phase would investigate the integration of tunnel ventilation controls to the dynamic rating algorithm to determine how best to respond to planned emergency loading requirements and also how to predict in advance what short term ratings might be available given knowledge of the ventilation operating history and prevailing ambient conditions.

Phase 3 would examine the deployment requirements of such a system, paying particular attention to the methods available to obtain the input data for the rating algorithm. This would review the type, quantity and, most importantly, quality, of data sources already available on the National Grid network. Using historical data from the system it would be possible to investigate how well the algorithms would perform with realistic system inputs. Where insufficient input data sources are available for a particular application, recommendations would be given for future installations.

Once the algorithms are operational and have been benchmarked against experimental data sources within the Laboratory, the final phase of the project would seek to define the benefits available from such a system based on previous operational circumstances. Circuits which are primarily

	constrained by cable would be identified and investigations set up within National Grid to determine whether these particular circuits have been linked to constraint costs in the past. Based upon system loadings and the prevailing environmental conditions at the time, the dynamic rating algorithms will be applied to ascertain what level of load could have been realistically supported by the system for the duration of the constraint. This will permit an outline financial analysis to be undertaken within National Grid to discover whether the constraint cost could have been reduced had it been possible to utilise the dynamic rating algorithm at the time. This phase will also involve working with Network Operations to both obtain data, but also to help identify potential target deployments which would offer the greatest operational benefit in terms of constraint relief. Ultimately, the project will lead to the description of dynamic rating algorithms suitable for application to a wide range of transmission cable circuits, along with analysis of the potential benefits in terms of both cost reduction and increased system flexibility that would be available to National Grid were such a system to be used.			
Type(s) of innovation involved	**Significant**	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		10	**-11**	**21**
Expected benefits of project	Cable circuit ratings have been, and continue to be, the subject of active research within National Grid, with a number of important changes to standards having already been identified in previous projects. While this has led to significant advances in the cable rating calculations required for system planning, when it comes to the application of short term ratings it is difficult to ascertain whether the static calculation provides a true picture of the system capability. The future deployment of dynamic rating algorithms as an operational tool will both reduce system risk (through providing a more detailed picture of the actual status of a cable circuit) while potentially allowing higher short-term emergency ratings than the existing calculation methodology. This could offer major financial impacts in terms of reduced generation constraint costs in the future. For example recent cable rating enhancement requests have resulted in cost savings of between £41k to up to £4M based on estimated constraint costs avoided. The ability to apply enhancements dynamically could potentially avoid this level costs routinely. In addition the increased use of renewable generation in the future will require the need for highly flexible operation. Dynamic rating methods will enable flexibility by making best use of favourable ambient conditions. Through the course of this project, National Grid will gain: • Understanding of how to develop dynamic ratings algorithms • Recommended dynamic rating techniques for a variety of installations, with results verified by experiments. • A framework for the future implementation of dynamic cable circuit ratings, including an assessment of the optimum input data provision. • Quantifiable investigation into the benefits of using such a system operationally, with an indication of the possible reduction of system constraint costs.			

	The above will bring the following business benefits: • National Grid will be clearly informed of where the use of dynamic ratings techniques on an operational basis could provide a constraint cost saving. • National Grid will be in possession of a framework for implementing such algorithms on candidate cable circuits. • The deployment of such algorithms would also assist in identifying cable circuits which have suffered a change in thermal environment. • The use of dynamic ratings algorithms would reduce the risk to the system from the use of emergency ratings through a more comprehensive understanding of the thermal condition of the cable circuit.		
Expected timescale of project	3	Duration of benefit once achieved	8
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	201064
Potential for achieving expected benefits	This proposal seeks to build on a successful record of work relating to modelling of HV cable systems at the University of Southampton. • The Tony Davies High Voltage Laboratory has over 50 years of experience of using both numerical modelling and experimental work to improve cable rating calculations. • Previous National Grid funded work in the area of cable system thermal modelling has identified situations which can not be analysed using conventional (International Standard) methods and provided bespoke solutions. • Staff at the University of Southampton have extensive experience of providing cable rating support to National Grid, particular in the areas of numerical modelling and the provision of independent verification. Although it is difficult to extrapolate performance measures and experience, the track record outlined above leads to the conclusion that it is highly likely that this group will be able to: • Develop dynamic rating algorithms suitable for application to a wide range of cable circuits • Benchmark such methods against realistic laboratory experiments • Identify potential deployment options for the technology which would stand to offer financial benefits to National Grid.		
Project progress [Year to End of March 2013]	The project started with work on the Literature Review. The literature review is complete and reported. Work has been carried out to benchmark two existing dynamic rating techniques against a finite element model. The assessment indicates that improvement in rating performance can be achieved from one of the techniques. An interim report considering different rating algorithms for buried cables has been provided. The next stage is to consider cables in air.		

Collaborative partners	
R&D provider	**University of Southampton**

Project title	Modelling and analysis of potential installations and uses of grid scale Energy Storage in Great Britain.		
Project Engineer	Tim Bradley		
Description of project	The Project will adapt and significantly expand existing energy storage models so that they reflect data, inputs and assumptions that are relevant to the GB grid, and on the basis of this to model certain potential uses of energy storage on the GB grid. Specifically, the focus will be on: • Energy storage used as a source for certain Balancing Services needed for grid stabilization, such as STOR, fast reserves and frequency response, and • Energy storage used to reduce future needs for such Balancing Services by shaping wind power so that it presents less of a threat to grid stability, i.e. directly addresses wind power intermittency by "shaping" wind power production into flat blocks of power thereby reducing some of the grid's need for these Balancing Services. The aim of the Project will be to provide useful and potentially important operational and financial insights with respect to these uses of energy storage and with respect to whether these uses of energy storage could be effective and economical as ways to address some of the key challenges that the GB grid is expected to face in the future.		
Expenditure for financial year 11/12	Internal £5k External £91k Total £96k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£91k	Projected 2013/14 costs	£0k
Technological area and/or issue addressed by project	With the rapid progress in the deployment of renewable energy sources, primarily offshore & onshore wind, in the UK the question of how to integrate this intermittent power into the electricity transmission network is increasingly being heard and will rapidly become a cause of major concern as the penetration of renewable energy increases over time; greater than 30GW of wind power generation capacity is expected to become available by 2020 and that is set in the context of peak demand of 55-65GW. Also, as a result of the increased intermittency from these power sources it is forecast that a substantial increase in balancing services requirements will be seen over a similar timeframe, perhaps by as much as 100%, primarily based on the requirements for the Short term operating reserve. There is also a good deal of debate about how frequency response requirements will be affected. Grid-scale energy storage is increasingly being seen as a game changing technology that can provide a solution to the integration issue whilst also being capable of participating in the balancing services space. Traditionally, large scale energy storage has been provided by pumped hydro facilities and a small number of compressed air energy storage facilities, however these facilities are constrained by geographical		

	parameters and high capital cost. More recently, advances in alternative technologies, most notably battery and flywheel technologies, suggest that significant changes to the energy storage delivery solutions are potentially within reach. Indeed there are now several examples in the US where these technologies have delivered benefits in the integration of renewable energy generation functions into the existing energy delivery systems, or the provision of a peak load shifting capability that enables more efficient network investment decisions to be taken, or by offering more efficient and cost effective system balancing services to system operators. National Grid has formed a broad stakeholder group to evaluate the opportunity for developing and executing a successful grid scale energy storage demonstration project. Members of this group include 24M, Xtreme Power, Premium Power, A123 and Beacon Power with its UK Agent Gaelectric (note: Beacon Power filed for Chapter 11 bankruptcy protection the US in November 2011).			
Type(s) of innovation involved		Project Benefits Rating	Project Residual Risk	Overall Project Score
		3	-5	8
Expected benefits of project	With approximately 30GW of wind power generation capacity becoming available by 2020 and with the increased intermittency in power supply that these power sources will bring, it is forecast that a substantial increase in reserve and balancing services requirements will be seen over this timeframe which will bring significant challenges to the System Operator in dealing with the characteristics of the new generation plant. For instance the reserve requirements opportunity is forecast to increase from 3.5 GW in 2010 to ~8GW by 2020 with costs forecasted to rise from ~£260m in 2010 to >£550M in 2020. Energy storage technologies will be potentially significant service providers for this growing market opportunity and are seen as potentially being a key technology in the delivery of the UK's vision for a low carbon energy industry (reference Energy Research Partnership Report on The Future Role of Energy Storage in the UK and National Grid's Operating The Electricity Transmission Networks in 2020). The introduction of energy storage may offset or reduce the need to build additional fossil fuel generating plant that would otherwise be needed to provide the additional reserve and balancing services resulting from the greater proportion of wind power in the energy mix and therefore will have a substantial carbon reduction benefit. An additional benefit may be that by 'smoothing' the flow of energy onto the grid by managing the peaks, the network will be more resilient and thus the investments required for transmission capacity upgrades may be reduced. The immediate benefit to National Grid of this work is the advanced knowledge to be gained about the potential impacts of these types of technology on the ability to procure balancing services and wind integration services in the future and how they might impact on the ability to operate the system. Quantified long term benefits of this work are unclear at this stage but the work will contribute to our understanding of the key issues around this			

	topic.		
Expected timescale of project	1 year	Duration of benefit once achieved	3 years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-91651
Potential for achieving expected benefits	The development of knowledge will be used to influence future decisions on the utilisation of large scale energy storage. The Energy Storage companies have good track records and the facilities to undertake this work. Four of the five companies have existing operational experience in the US and the fifth company, 24M, has substantial ties to MIT and a close relationship with A123. The likelihood of success from the partner perspective is very high. Overall success in the project will also be dependent upon National Grid itself to provide detailed knowledge and information around the UK's regulatory and commercial market mechanisms. National Grid will also be responsible for the provision of relevant operational and commercial data that will be needed to facilitate the modelling process. Significant effort will be needed from National Grid Transmission Commercial and Network Operations staff to enable the modelling activity to be carried out in a timely and efficient manner. Overall likelihood of success is high.		
Project progress [Year to End of March 2013]	This project has now completed and resulted in the following; a) completion of a desktop study b) output report on the study c) the development of a tool to consider the use of energy storage to different wind generation scenarios. This work mainly focused on the technical requirements of balancing, considering how an energy storage device could be optimised based on the variation in wind forecasting/output seen at a particular site at the 4 hours prior to real time period. In summary, this work can be considered to be the first step in understanding the potential role(s) of energy storage at transmission level. It is believed that significant further work would be necessary to determine the overall benefits and to whom those benefits could accrue. This first piece of work has given National Grid an insight to how energy storage could help reduce the volumes and costs of balancing the system based on associating an energy storage device directly with intermittent generation such as wind farms. Next phase work could consider where additional benefits could be gained, this includes considering the use centralised energy storage to manage intermittency (system operator (SO) focus) and, from the transmission operator perspective use of energy storage to defer reinforcement. Under this scenario it would be expected that the asset would have capacity outside of peak shaving requirements to participate in other markets, benefits to the SO in the form of balancing services and to the wholesale market.		

Collaborative partners	
R&D provider	**24M**

Project Title	**Novel Use of Distribution Equipment for Power Quality Management**			
Project Engineer	**Lauren Moody**			
Description of project	**Electricity Northwest has approached National Grid with a proposal to test the novel use of distribution equipment for providing additional power quality management options as part of Low Carbon Network Fund submission.** **The aim of this project is to provide upfront technical input to the preparation of a Low Carbon Network Fund (LCNF) bid to ensure that the scope of the full project adequately addresses National Grid's requirements relating to communication protocols, reliability and network implications such that National Grid has confidence in the wider deployment of these techniques across all distribution networks and can robustly compare them to alternative methods of managing power quality.**			
Expenditure for financial year	**Internal £12k** **External £2k** **Total £13k**	**Expenditure in previous (IFI) financial years**	**Internal £0k** **External £0k** **Total £0k**	
Total project costs (collaborative + external + [company])	**£k**	**Projected 2013/14 costs for National Grid**	**£0K**	
Technological area and/or issue addressed by project	**As volumes of wind generation and other low inertia plant increases on the GB system, and the proportion of predictable and flexible generation decreases, the challenge of maintaining system stability and power quality become greater; in particular frequency control and voltage management.** **Various options are potentially available for maintaining stability/power quality in the future ranging from demand side participation from individual consumer appliances to running thermal plant as spinning reserve.** **All options are coupled with social, economic or environmental compromises, and range considerably in terms of technology readiness.** **The LCNF project aims to demonstrate, to the point of readiness to fully implement, an additional option for frequency control and voltage management that makes use of existing distribution assets.**			
Type(s) of innovation involved	**Incremental**	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		6	**-10**	**16**
Expected benefits of project	**This project will provide National Grid the opportunity to ensure that the LCNF project provides outputs that meet National Grid's requirements. The bid project will provide access to future financial support for National Grid under the LCNF project to develop the necessary control and communication systems and modelling tools to deploy this frequency control**			

	and voltage management option in the future. The LCNF project will give rise to a number of potential benefits to consumers and to National Grid. A preliminary evaluation by the University of Manchester identifies the potential to deliver savings of £150m per year UK wide, or put another way £6 per household per year by providing alternative power quality services. From a National Grid transmission operator perspective the project could also reduce, or at least defer, the need to install shunt reactors and Mechanically switched capacitors (MSCs) for reactive power management. Investment in reactive power management assets totalling ~£70 million is forecast for the RIIO T1 period. Avoiding the need for just one shunt reactor would save an estimated £5-£7 million.		
Expected timescale of project	1 Year	Duration of benefit once achieved	8 years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£0
Potential for achieving expected benefits	The technical aspects of the LCNF project are well understood. Primary challenges lie in demonstrating the reliability and knock on consequences of triggering a response from the DNO and ensuring reliable, compatible and secure communications links. The likelihood of value coming from the LNCF project is almost certain as it will either demonstrate that it is a viable option, or not: both outcomes have value. Based on discussions with ENW to date, there is a high likelihood that the LCNF project will succeed in demonstrating a viable additional option for frequency and power quality management at lower cost than other options.		
Project progress [Year to End of March 2013]	• ENW submitted the LCNF project bid for Customer Load Active System Services (CLASS) in August 2012 to Ofgem by ENW. It was approved by the LCNF expert panel in October 2012. • A contract signed was signed between NGET and ENW in March 2013 which sets out the accountabilities and deliverables for NGET. • While this report is for year end to March 2013, a National Grid project team has been mobilised with the first project meeting having since taken place in May 2013.		
Collaborative partners	Electricity North West & GE		

R&D provider	**ENW & GE**

<table>
<tr><th>Project Title</th><th colspan="3">Reactive Power Demand Trends</th></tr>
<tr><td>Project Engineer</td><td colspan="3">Clive Coles</td></tr>
<tr><td>Description of project</td><td colspan="3">The key objectives are to determine:

a) The factors behind the significant decline in reactive power demand and increase in the distribution network operator (DNO) system reactive power gain as observed at the Transmission/ DNO interface during periods of minimum daily demand observed over the last 5 years
b) Its relationship to the overall decline in active power at these interfaces during these periods.

Having looked at these factors, the project should then determine the most likely trends for reactive power in future years and produce a report providing forecast scenarios for the active and reactive power at these DNO supply interfaces. The assessment of the decline should attempt to identify how far the trend will decline (and at what point a "floor" might be reached) of reactive power exchange to the power system that might be expected overnight. Against this floor, further case study evaluation of the response of the network under such stressed conditions overvoltage disturbances (e.g. failure of a shunt reactor or major provider of reactive power absorption) is to be used to determine minimum pre- fault levels of voltage profiles available to be adopted to prevent insulation breakdown and other modes of cascade failure emerging.

The project will need the Energy Networks Asssociation (ENA) and DNO engagement with the university project. The later stage of the project is more transmission network focussed. Network gain should be broken down into the fixed component of the transmission network - DNO interface mentioned above, the loading of the transmission system at the time, and the inherent characteristics of that network {susceptance, saturation characteristics, controller & protection response} so as to improve understanding across these areas.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £4k
External £22k
Total £26k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£26k</td><td>Projected 2013/14 costs for National Grid</td><td>£0K</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="3">In the last 2 years, there have been significant difficulties in managing voltage levels during minimum demand periods. Analysis of this issue has shown that the root cause is likely to be related to the significant decline in reactive power relative to active power. Whilst minimum active power demands have fallen by around 15% in the last 5 years, reactive power has declined by 50% in this time. Current trends for 2012 show that this reduction is continuing, broadly, across the country. In order to better understand the challenge of managing voltage levels within limits and to plan for additional future reactive compensation requirements, a thorough understanding of the reactive power trend needs to be developed. A previous paper</td></tr>
</table>

	has highlighted some possible causes such as embedded generation growth, increasing use of energy efficient equipment and impact of austerity measures (e.g. reduced use of street lighting). Further work on these and other potential causes (e.g. combined heat and power, electric vehicles) is required.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score
		9	-4	13
Expected benefits of project	Voltage levels are required to be maintained within the capability of power system equipment. Should these not be achieved, National Grid could risk the safe operation of the network and potentially face financial or reputational impact by regulator reaction. Voltage control is achieved in the first instance by utilising reactive compensation, and then utilising the reactive capability of generating plant. Currently significant sums (circa £50m/year) are being spent on buying generation overnight to provide sufficient reactive management capability in specific geographical areas. In addition, a potential spend of £130m over the next few years is likely to be required to buy additional shunt reactors to manage the high voltage issues being experienced. Issues which may impact this further are 400kV route upgrading, amenity pressures for selective undergrounding of new routes, and the effects of interconnector exchanges which reduce network flows and hence reactive losses. In order to ensure efficient and timely expenditure, an understanding of the decline in reactive power is needed so that future system design studies can more accurately predict voltage levels over minimum periods which will result in a) efficient procurement of reactive plant requirements such as new shunt reactors. b) ensure sufficient actions such as contracting generation are undertaken in the interim period while other operator actions are developed.			
Expected timescale of project	1 year	Duration of benefit once achieved	8 years	
Probability of success	80%	Project NPV = (PV benefits – PV costs) x probability of success	£354,596	
Potential for achieving expected benefits	The project should prioritise high levels of DNO engagement to obtain a granular breakdown of the effect at the DNO interface. This includes the effects of network operation, demand, generation and the distribution system, and be clearly illustrated, analysed and modelled to capture the magnitude of each factor to the effect at the Transmission- DNO interface. Such analysis should be captured in draft reporting and be presented and critiqued ahead of further work. From such analysis the project should then be able to identify the key causes of reactive power decline within the timescales.			

	The project will then need to estimate future trends in these factors over the next 8 years. It is accepted that these factors may have a degree of uncertainty, and use of forecast scenarios may be applicable such that a range of outcomes together with an indication of the most likely trend is produced. It is expected that the project team will obtain operational data from the DNOs of their network state, demand and generation characteristics and voltage profiles, such that the effects under consideration may be accurately replicated and tested via use of AC load-flow analysis. This may be augmented with Transmission system representation to deliiver transient overvoltage assessment. In assembling forecasts, close dialogue with DNOs and National Grid's forecasting team, referenced by external metrics (e.g. regional economic output data and forecast, trends in embedded generation development and availability/ economics) should be examined and validated against historic analysis.
Project progress [Year to End of March 2013]	▪ A workshop at National Grid with DNOs and the University of Manchester was help in September 2012 as the first step towards formulating key questions that the reactive project should address. This led to all DNOs and academics working together in a partnership to carry out a 2 year research in leveraging expertise and capabilities across all stakeholders to meet this challenge. ▪ A Road Map and an information gathering request on 5 key areas was agreed by DNOs (two DNOs have already satisfied the first process of data gathering). ▪ A report (Volt-VAr Regulation in UK Distribution Networks) describing the current practices in UK distribution networks regarding voltage and reactive power regulation was prepared by Manchester University on 25th October 2012. ▪ The Road Map agreed was used by National Grid to update Ofgem as to progress in this area by the key stakeholders on 21st November 2012. The update was given after 165 voltage excursion events were reported to under regulatory requirements (C17 Licence obligations) for 2011/12. Ofgem agreed to the plans, but requested further updates if there was any significant deterioration or significant developments with this research work. There was an expectation of another meeting in October 2013 (yet to be confirmed). ▪ 3 DNOs have already signalled their intent to collobrate on the project and it hoped that another 2 DNOs will confirm that they will join the project. ▪ The strategy was to utilise ENA to help coordinate DNO senior management awareness and continued support for this project. The aim is to set up a further

	stakeholder workshop in 2013.
Collaborative partners	**DNOs**
R&D provider	**Shanti Majithia (ECAS), University of Manchester**

Project Title	**Modelling of Embedded Generation within Distribution Networks and Assessing the Impacts on Load Profile at Transmission Level Grid Supply Points (GSPs)**		
Project Engineer	**Djaved Rostom**		
Description of project	• A literature review on various assumptions and methodologies adopted for modelling embedded generation in distribution networks for power system planning in the GB system (e.g. P2/6 Standard). • Investigation of different methodologies and their effectiveness in modelling the impacts of embedded generators on load profiles at distribution and transmission level. • Investigation of contribution factors responsible for large, small and medium mismatches. • Development of alternative modelling methodologies, using the identified key contribution factors to minimise the mismatches between the modelled and measured results. • Testing and validation of the developed modelling methodologies on selective number of GSPs. • A report documenting the key findings.		
Expenditure for financial year	**Internal £4k** **External £0k** **Total £4k**	**Expenditure in previous (IFI) financial years**	**Internal £0k** **External £0k** **Total £0k**
Total project costs (collaborative + external + [company])	**£32k**	**Projected 2013/14 costs for National Grid**	**£28K**
Technological area and/or issue addressed by project	**The transition to a low carbon economy will see a substantial rise of renewables in our energy mix. By 2030, around 48 GW of wind is expected to be installed on the GB system, of which, up to 40% is expected to be connected at distribution systems, ranging from low voltage (LV), high voltage (HV) to extra high voltage (EHV). This will fundamentally change the demand patterns seen at the Grid Supply Points (GSP) connecting to the transmission system. Currently there are no reliable tools to determine the accurate impact of distributed generation (DG) on the demand patterns at the transmission level, particularly, considering the effects of DG concentration, location and penetrations across the three voltages.** **This project will develop methodologies to identify the collective effect of DGs on the national transmission system, so as to reduce load forecasting errors, which will in turn reduce the level of operational reserve. This will ultimately lead to much improved balancing efficiency and carbon efficiency. Furthermore with the increased visibility on embedded generation, which this research is expected to deliver, a more accurate representation of the demand can be used in planning the system.** **The development will establish an understanding of the current practices, analysing their relative efficiencies at modelling DG effects for designing the system as per the Security and Quality of Supply Standards (SQSS). The analyses will highlight**		

<table>
<tr><td></td><td colspan="4">conditions and factors that improve or worsen the above efficiencies. Using the results of these analyses, the project will investigate a number of candidate techniques to determine the nature and magnitude of the impact of distributed generation to transmission demand.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>4</td><td>-10</td><td>14</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">A number of benefits are expected to be achieved from the realisation of this project.

In planning timescales, having a clearer representation of the embedded generation in our demand or generation models will certainly improve the accuracy of the system studies carried out by National Grid. Planning the system against a more accurate demand background will help to identify more efficient reinforcements or measures that can be taken to facilitate the operation of the system in the future.

Key benefits include:

• Clarification on the contribution of embedded generation to meet local demand and the load profile at GSP points.
• Accurately sizing the SGTs and avoiding constraints on the network as per Chapter 3 Studies of SQSS.
• Clarity on what information may be required from DNOs, and whether GSR009 assumptions with regard to embedded generation contribution can be accurately applied for all types of generators including embedded generation.
• The project will also highlight the limitations of the current standards such as the P2/6 and the SQSS with respect to modelling embedded generation. The developed tool will provide insights into more suitable methodologies to reflect the DG effects at the transmission level. This work will feed directly into SQSS working group on alignment of SQSS with P2/6 .
• The project will also facilitate better commercial and technical interaction between TSO/DNO for now, and between TSO/DSO in the future.
• By better modelling embedded generation contribution to load profile at GSPs, the issues currently affecting National Grid in terms of voltage and reactive power management, can be rectified. Better solutions therefore can be recommended i.e. widening the reactive power range at the GSPs (through interaction with relevant DNO).

The contribution of embedded generation to demand security during faults can be crucial to alleviate constraints on the network. The contribution of embedded wind is conservative at the moment (5% of max capacity). Depending on the findings of the research, the reduction in constraint costs that can</td></tr>
</table>

	potentially be obtained by 2030 varies between 2% (for 10% embedded wind) to 9% (for 30% embedded wind). This is estimated to be equivalent to an average saving of £2 -10 Million per year.		
Expected timescale of project	2 years	Duration of benefit once achieved	up to 20 years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£-3502
Potential for achieving expected benefits	The project will certainly provide a detailed understanding of the impact of embedded generation on the demand seen at the transmission level. The first stage of the project involves a detailed analysis of the current methodologies and an assessment of their effectiveness at modelling embedded generation. It is highly likely that this will be achieved within the estimated timescales. The second stage of the project will focus on the development of new methods and will therefore involve an innovative approach. However, backed by the research on the current standards which stage 1 will achieve and the extensive testing and validation phases that have been planned for stage 2, it is also very likely that the final objectives will be met within the set timescales.		
Project progress [Year to End of March 2013]	The project was split into four work packages with deliverables defined for each work package. The list below shows the worked planned. Work Package 1: Literature review on various assumptions and methodologies for modelling embedded generation (EG) in distribution networks and Investigation of different methodologies and their effectiveness. Work Package 2: Investigation of the contribution factors for large, small and medium mismatches + Interim report documenting key findings. Work Package 3: Development of alternative modelling methodologies aiming at minimising the mismatches between modelled and actual EG contribution. Work Package 4: Test and validate the developed modelling methodologies on a selective number range of GSPs, further enhance the alternative modelling and develop a set of rules based on the analyses. Final Report The current status of the project is that work package 1 has been successfully delivered. The research student from the University of Bath reviewed the current P2/6 standard that is adopted by the DNOs and proposed a new methodology to improve the assumptions made when assessing the		

	contribution of embedded generation to demand security. A research paper has been submitted to National Grid. **The project was put on hold subject to negotiations. Work package 2, 3 and 4 remain to be carried out by the University of Bath.**
Collaborative partners	
R&D provider	**University of Bath**

Project Title	**Optimised location for surge arresters on the transmission network**				
Project Engineer	**Dongsheng Guo**				
Description of project	**1- To review existing practice of surge arresters and related insulation coordination. 2- To develop models for key scenarios of transients (lightning and switching) in transmission substations. 3- To develop simple rules and techniques for optimising the use and location of surge arresters in substations. 4- To develop necessary background knowledge for overvoltage protection of transformers, gas insulated switchgear (GIS) and cables. 5- To investigate overvoltage protection special cases of transformer fault scenarios and GIS-Cable networks. To obtain the EMTP (electromagnetic transient program) simulation models of all above tasks and activities.**				
Expenditure for financial year	**Internal £5k External £33k Total £38k**	**Expenditure in previous (IFI) financial years**		**Internal £0k External £0k Total £0k**	
Total project costs (collaborative + external + [company])	**£64k**	**Projected 2013/14 costs for National Grid**		**£42K**	
Technological area and/or issue addressed by project	**R&D work is required to assist the review and update of National Grid documents that affect insulation coordination aspects of transmission substations, e.g. Policy document PS21 and Technical document TGN27. In particular, it is important to investigate the overvoltage levels within a substation under both lightning and switching surge conditions. This would allow adequate choice of surge arresters and, more importantly, determine an optimised location for more effective and reliable overvoltage protection of high voltage plant, e.g. transformers, cables and GIS.**				
Type(s) of innovation involved	**Incremental**	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**	
		8	**-7**	**15**	
Expected benefits of project	**The policy and technical document suite will be streamlined and as a result of this, construction delivery units would be able to develop more appropriate designs, in a timely and cost-saving manner. Cost saving will be achievable on a number of levels, firstly this new knowledge should reduce uncertainty and re-engineering scheme time, estimated in the range of £10~20k per scheme (4-5 pa). Saving will also be achieved through the removal of some insulation coordination studies, estimated to be 3~4 cases per annum at circa £50k each. It is also possible that the R&D may suggest the omission of surge arresters from some GIS applications, which will lead to a saving of circa £500k per set.**				

Expected timescale of project	**2 years**	**Duration of benefit once achieved**	**8 years**
Probability of success	**40%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£74527**
Potential for achieving expected benefits	**The likelihood of success is high, due to clearly defined/agreed objectives, the working relationship between National Grid and the supplier, and the capacity/reputation of the supplier in this technical area.**		
Project progress **[Year to End of March 2013]**	**A literature review has been carried out on** **(i) surge arrester protection distances and effect on overvoltage performance.** **(ii) EMTP models of zinc oxide (ZnO) surge arresters.** **(iii) Modelling guidelines for Very Fast Transients in GIS substations.** **Preliminary models of transmission substations under lightning and switching transients have been developed.**		
Collaborative partners			
R&D provider	**Cardiff University**		

Project Title	Power System Oscillation Damping with HVDC (POD) - Feasibility Study		
Project Engineer	Biljana Stojkovska		
Description of project	This feasibility project will deliver important knowledge and understanding on the effectiveness of damping with HVDC using different control strategies. This is the key to underpinning immediate post contract negotiation with offshore wind farm developers for the Celtic Array and Hornsea wind farm. The objectives of this consultancy project are to: i) assess how power oscillation damping (POD) will help to damp the low frequency oscillation (LFO) in the network ii) Investigate effectiveness of control strategies for better stability of the GB transmission network. The research project will provide: 1.) Results on the effectiveness of modulation of only reactive power of the HVDC onshore end converter with no active power modulation from the offshore wind farm. 2.) Results on effectiveness of active power modulation from the offshore wind farm if there is a delay in the control signal to the wind farm. This short project completes investigations into basic control philosophy options previous investigated by Imperial College and presented to National Grid.		
Expenditure for financial year	Internal £4k External £13k Total £16k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£16k	Projected 2013/14 costs for National Grid	£0K
Technological area and/or issue addressed by project	National Grid is being challenged by offshore wind farm developers on whether power oscillation damping is required and the control philosophy that National Grid has specified in Bilateral Agreements. The knowledge provided by this research will allow National Grid to justify the control philosophy included in the Bilateral Agreements as the most effective. It is important to mention the existing HVDC interconnector does not provide POD. It is proposed that Imperial College will undertake work to establish this understanding and to propose alternative control strategies that might be practical to apply to a real power system.		

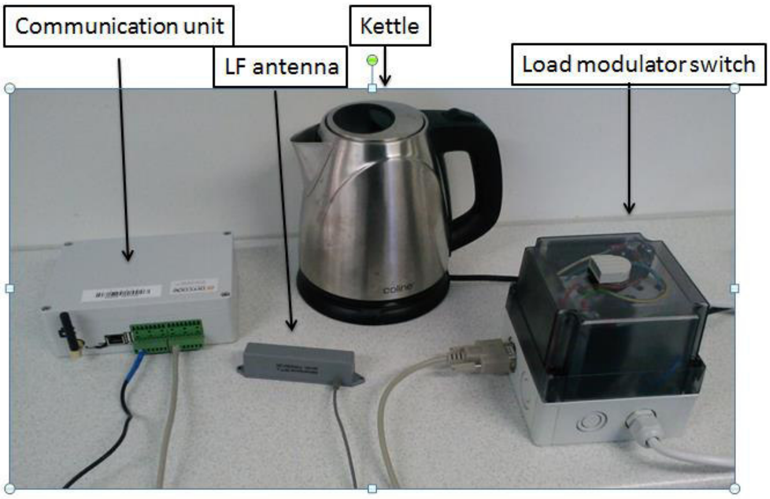
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		12	11	23

Expected benefits of project	**National Grid has already identified that the displacement of traditional synchronous generators by wind farms will potentially cause low frequency oscillation in the GB network. Additional HVDC connection of offshore wind farms will make situation even worse. Achieving the POD from HVDC connections will avoid a need for further investment in overhead lines or generation constraint to damp a power system oscillation in the network. Potential savings in wind farm generation constraint could be £20 million per annum. This project is contributing knowledge that could be critical in achieving this benefit, attributing an estimated 2% of the overall benefit per annum to this project if the study proves to be successful.**		
Expected timescale of project	**1 year**	**Duration of benefit once achieved**	**8 years**
Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£770,861**
Potential for achieving expected benefits	**There is high change of success of understanding the impact that power system oscillation damping using HVDC could have on the system. Imperial College have previously produced work in this area and have delivered a number of projects for National Grid.**		
Project progress **[Year to End of March 2013]**	***The project achievements are the following:*** **1.) Results on the effectiveness of modulation of only reactive power on the HVDC onshore end converter with no active power modulation from the offshore wind farm.** **2.) Results on effectiveness of active power modulation from the offshore wind farm if there is a delay in the control signal to the wind farm.**		
Collaborative partners			
R&D provider	**Imperial College**		

Project Title	ROGER		
Project Engineer	David Bunney & David Mills		
Description of project	Project "Roger" seeks to develop, install and verify that coordinated control of appliances in domestic and commercial premises can be detected and operated to provide the System Operator with a balancing product. More specifically, it is to evaluate whether Grid-Metrix technologies from Reactive Technologies Ltd are able to provide measurements of power consumption of distributed loads in a realistic distribution/transmission network setting. This will enable a more accurate assessment of loading on substation transformers. The project will install 30 demand devices of 3 kW range rating at normal 240V single phase distribution levels within a single grid supply point area. The on/off state of these devices will be controlled in a coordinated manner by a simulated services aggregator function, which will send programme signals to a controller box. During the trial period, the electricity demand profile will be sampled from meters in substations and state-of-the-art signal processing algorithms previously deployed in mobile telecommunications devices will be tested for their detection capabilities. The project aims to prove that small loads in the kW range in a domestic and small and medium enterprise (SME) setting: 1. Can be controlled by remote signal / or by time-synchronised programme. 2. Can be coordinated to act together in a manner useful to the grid. 3. Produce signals which new cutting-edge technologies in signal processing may detect at the meter-points in transmission and distribution substations.		
Expenditure for financial year	Internal £5k External £37k Total £42k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£42k	Projected 2013/14 costs for National Grid	£0K
Technological area and/or issue addressed by project	In order for the electricity transmission grid to function correctly and provide security of supply, the amount of generation input and consumption off-take from the grid must be balanced at all times. As the generation-side of this equation moves to more volatile weather-dependant sources, additional mechanisms for achieving power balance will become more crucial. Demand-side management is expected to play a major role in the energy balancing mix and it will become increasingly important to be able to control the timing and levels to which households draw power from the grid for applications such as space and water heating. By having access to facilities which can adjust demand, or minimise peaks, it is believed that critical maximum temperatures in expensive assets such as		

	transformers can be controlled, thereby extending their lives. Whilst large industrial loads have contributed to balancing services for many years and the theory of demand-side management and 'smart-grid' technologies have been developed, the complexities of controlling individual appliances within a domestic or SME environment has yet to be deployed into mature services. The emphasis is on controlling individual appliances in a way which does not affect their enjoyment by consumers, whilst successfully aggregating these power control functions into useful and measurable mechanisms for the grid operators.			
Type(s) of innovation involved	Incremental	Project Benefits Rating 9	Project Residual Risk -9	Overall Project Score 18
Expected benefits of project	A successful demonstration of smart-grid technologies in a coordinated and measurable manner will be of immensurable value in moving forward the concepts of smart-grid and demand-side management. The accurate assessment of transformer loading will also enable asset life and condition assessment of assets to be undertaken thereby reducing the need for asset replacement investment. Benefit is deferred asset replacement, conservatively estimated as £100k per year based on a single transformer deferment. This project will allow further work into understanding the actions which may be taken by demand-side, and subsequent projects are expected to investigate rate-of-response, MW level of response and duration for which this may be provided.			
Expected timescale of project	1 Year	Duration of benefit once achieved	8 Years	
Probability of success	70%	Project NPV = (PV benefits – PV costs) x probability of success	£13770	
Potential for achieving expected benefits	There is a high probability that this project will deliver its objectives as, separately, most components have been used in other applications or been successfully tried in the laboratory. ▪ The controllers to be deployed by Reactive Technologies have been built and tested in the laboratory; ▪ The metering interface requirements are understood; ▪ The signal processing technology whilst new in power-electronics, is now widely used in telecommunications applications; Additionally there is good cohesion and communication			

	between Reactive Technologies, SSE, and National Grid ensuring that any logistical issues are identified and resolved quickly. Also, there has already been a successful in house trial of the testing methodology.
Project progress [Year to End of March 2013]	National Grid , SSE, and Reactive Technologies (RTL) agreed to collaborate on a trial to demonstrate RTL's Grid-Metrix technology. The technology uniquely allows the instantaneous measurement of participating load-bearing devices from National Grid's Grid Supply Point (GSP) infrastructure (132kV sub-station). The key objective for the ROGER trial was to validate the Grid-Metrix measurement concept. This was accomplished by developing 30 load modulation units (with each one having an associated 3 kW water kettle as a load) and co-ordinating the load modulation by RTL's cloud based control platform. The loads were connected at the single phase 240 V level of various consenting customers on the SSE network supplied from the National Grid Amersham GSP. The aggregate power variation signal was then measured at the National Grid Amersham GSP. Analysis of the measurements collected during the trial successfully showed the Grid-Metrix technology to work. At various points during the 2 day period the loads were modulated in a range of time and load patterns. Processing of the measurement data showed the modulation patterns were detectable and that the Grid-Metrix technology worked for all the selected load modulation patterns. The initial Grid-Metrix correlator design measured the absolute power of the load modulation as 84 kW as opposed to the actual of 82 kW. The dynamic sensitivity of the initial correlator design was confirmed to be about 10 kW, further work was identified by RTL to improve the correlator design and measurement set-up to further improve the accuracy. The successful validation of the Grid-Metrix technology opens the opportunity for interested parties to develop new balancing/ancillary service concepts and other TNO/DNO/Energy company value adding services which benefit from the instantaneous power measurement of the loads contributing to the service. Furthermore, modulation code design will allow assigning distinct codes to the loads allowing fast instantaneous power measurements based on e.g. load type or load geographic location. As multiple loads are aggregated through shared use of given code the privacy of whether given users loads contribute to the service is ensured. Next steps for the service development are to identify potential current and new ancillary/balancing services and the unique value add of Grid-Metrix to those services. This phase would also include top level system design and validation for the Grid-Metrix technology in a real commercial service context covering a large geographic area and multiple Grid Supply points.



Collaborative partners	**SSE plc (http://www.sse.co.uk/)**
R&D provider	**Reactive Technologies Ltd (http://www.reactive-technologies.com/)**

Project title	SmartZone project		
Project Engineer	Mark Osborne		
Description of project	The SmartZone project will develop and pilot a range of intelligence based applications to enhance the boundary rating and network utilisation, this includes dynamic rating, new operational tripping and wide area monitoring control and protection (WAMPAC) tools, with the intention to have these production ready for National Grid to deploy where constraints or ‘Connect & Manage’ dictate. The trial will be a staged programme based in the Humber group to develop a ‘fit for purpose’ communications and data management architecture capable of providing Smarter Transmission. The project will commence in 2011 and aims to have production tools by the end of 2014. In summary, the pilot will intend to: 1. Install a variety of sensors to collect system and asset data. 2. Develop a number of applications which enhance asset performance of circuits and transmission boundaries or enable post fault capacity beyond current deterministic levels. 3. Design the appropriate architecture and identify the upgrades necessary in the IS infrastructure to support these new tools. 4. Understand the impact these applications will have on existing operation and procedures. Stage 1 will look at the end to end issue around installing one application (2010-11), while stage 2 will expand the range and scope of applications (2011-13) and stage 3 concentrates on the implementation programme into daily operation (2013-14).		
Expenditure for financial year	Internal £41k External £0k Total £41k	Expenditure in previous (IFI) financial years	Internal £73k External £356 Total £430
Total project costs (collaborative + external + [company])	£471k	Projected 2013/14 costs for National Grid	£160k
Technological area and/or issue addressed by project	The Humber estuary is going to be a key import/interface region for offshore generation and as such will be a major beneficiary of developments in dynamic rating and congestion management. The Electricity Networks Strategy Group (ENSG) report ‘Our Electricity Transmission Network: a vision for 2020’ provides greater detail on the network expansion. There are a number of new technologies being considered which can be used to extract or utilise more capacity out of existing assets through better intelligence on the parameters which determine the thermal operating limits of assets. Overhead line circuits are very dependent on weather conditions, so are obvious candidates for dynamic enhancement, especially since this will be coincident with the peak output for intermittent generation sources like wind. Improved network data will enable a new breed of automatic control and		

	protection schemes to be developed.				
Type(s) of innovation involved	**Significant**	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**	
		16	**2**	**14**	
Expected benefits of project	**The strategy documents WAMPAC (SD010) and Smarter Transmission (SD01x) both advocate the need for this trial as an integral part of preparing the network for the future.** **Under Connect & Manage, constraints costs can definitely be expected to rise, to at least a mean of £50m pa, but most likely higher. It is not unreasonable to expect that basic improvements in dynamic rating, could permit up to a 5% increase in circuit thermal ratings, and in turn would reduce these costs by 10%; thus a £5m pa saving can be reasonably claimed. Although unproven and not integrated at this time, the installation of a dynamic line rating (DLR) system will cost approx £200k-300k/circuit. In terms of constraint saving on a specific circuit this could equate to between £350k & £750k a day. Across the constraint boundary the saving is typically 2-3 times higher so the constraint savings could be in the order of £1m-1.5m.** **A range of asset awareness tools will be the key to facilitating system access ensuring connections, asset replacement and maintenance can be achieved.**				
Expected timescale of project	**4 years**	**Duration of benefit once achieved**	**5 years, until industry confidence is sufficient to revise Energy security policy regarding network design.**		
Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**£519k**		
Potential for achieving expected benefits	**The project will be carried out in a staged manner. Stage 1 involves establishing a dynamic rating pilot in the Humber. Phase 2 will expand this to wide area congestion management and WAMPAC tools, with Stage 3 concentrating on the implementation challenges for production tools.** **There is a reasonable likelihood of success in developing a working solution. The valuable experience gained during the pilot will help to reduce risks significantly during the enduring project roll out.**				
Project progress [Year to End of March 2013]	**The project has continued to deliver this year. There has been development in a number of areas regarding the analysis and specification of a wide area control and protection system for the Humber using network intelligence and dynamic ratings.** **Implementation of a field solution has been delayed to benefit from related smartgrid project learning on communication infrastructure and delivery costs.** **This is a multi work stream project. The key developments in 2012-13 include;** • **Presentations given at IET Smartgrid enabling platform, Manchester Jan 2013 'Using Smarter Transmission to integrate Renewable Energy & M2M World Congress, London April 2012.**				

	• Report: Humber Smartzone Operational tripping scheme design and modelling, using Phasor Measurement Units, Data Concentrators and fast Communication Infrastructure) – University of Manchester. • Report; Intelligent control: using dynamic line rating control of the operation tripping system – University of Manchester. • Draft specification developed for a substation Phasor Data Concentrator. • Wide Area Monitoring system using Open PDC software. • Acquired Electric Power Research Institute (EPRI) Wide area monitoring software (WAM).. • Report to quantify the economic impact of dynamic rating and power flow control on this region (University of Manchester). • Ampacimon Dynamic line sag sensors installed summer 2012. These have also been showcased at National Grid Leadership conferences. • Acquired testing equipment to evaluate performance of Wide area monitoring and control systems in the Manchester Protection and Control laboratory.  Installed Ampacimon sag monitor
Collaborative partners	Leverage will be sought through a number of channels and we will look to coordinate application development with Scottish Power and SSE. Work will be with solution providers to develop new tools (Alstom Grid, Siemens, Psymetrix) and coordinate with parallel National Grid Strategies SAM, RAMM, IS Smartvision ,etc
R&D provider	Multiple as applicable

Project title	Quantifying benefits and risks of applying advanced network control and demand response technologies to enhance transmission network performance			
Project Engineer	Amir Dahresobh			
Description of project	The research will inform and develop tools for the business to establish the benefits and risks, in quantitative terms, of adopting complex control methodologies (wide area control, automation & protection) in place of traditional reinforcement techniques. The project will run as three concurrent work-streams (PhDs): Workstream A will identify strategies for using advanced network control systems to improve system flexibility as alternatives to system reinforcement and constraints. The costs and benefits of each strategy will be determined. Workstream B will develop methods for understanding the impact on system resilience (SIL assessment) of the use of more complex control schemes, including higher levels of intertripping. The method will provide quantitative measures to allow relative comparisons of a range of network development options. Workstream C will provide information about current and developing demand management technologies. It will identify the extent to which they can be used to benefit system design and operation, and identify optimum levels of penetration.			
Expenditure for financial year 12/13	Internal £7k External £130k Total £137k	Expenditure in previous (IFI) financial years	Internal £5k External £170k Total £175k	
Total project costs (collaborative + external + [company])	£500k	Projected 2013/14 costs for National Grid	£140k	
Technological area and/or issue addressed by project	The electricity industry is undergoing a period of rapid change across all sectors – new generation technologies, unprecedented volumes and more remote locations; in addition demand characteristics will change, and new transmission system technologies are being constructed to absorb these changes. A full understanding of the impact of the changes and the potential benefits and risks associated with new technologies is needed, to ensure efficient development of the transmission system.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score
		9	3	6
Expected benefits of project	The use of control technologies will have significant impacts on the way the network is managed. In the design phase they have potential to reduce the need for difficult and expensive developments such as new circuits and introducing greater flexibility for the system operator is likely to reduce system constraints. However, as the control system complexity increases, the consequences of their failure become much greater, impacting on system resilience and reliability. The benefits of this project			

	will be to establish a mechanism to provide informed decisions on when the use of new technologies instead of more expensive development is appropriate, and when the risks are too great. In terms of cost impact, the failure to understand the risk and cost of a wide area control scheme properly could result in a range of impacts; ranging from an inability to reduce constraints across a boundary (£1-2m) to collapse or de-synchronisation between parts of the network and the cost of constraint or possible islanding which could be loss of demand and generation (£10m constraints). The project itself involves joint funding with Imperial funding of £320k via in-kind resourcing.		
Expected timescale of project	3 years	**Duration of benefit once achieved**	5 year
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£22k
Potential for achieving expected benefits	There is a medium, hopefully increasing to high chance of success. Whilst the scope of the project is large and complex, Imperial College have previously produced work in this area and have delivered a number of projects for National Grid.		
Project progress [Year to End of March 2013]	The three workstreams are delivering according to plan. The students have had a 6 week familiarisation period within National Grid to understand the challenges we currently face and our perspective of the challenges ahead. The students are working with National Grid engineers to develop models and studies which can evaluate a system wide controller, coordinated quadrature booster control and demand side management strategies. The students provided National Grid with the updates regarding their research in a technical presentation. National Grid technical leaders and managers participated in the presentation. The tools and smart solutions introduced in the theses were scrutinised and reviewed again. The recommendations about how they need to progress were also offered. The students are currently providing regular updates to National Grid following the technical assessment.		
Collaborative partners			
R&D provider	Imperial College		

Project title	Simulation of multi-terminal VSC HVDC system by means of real time digital simulator (RTDS)		
Project Engineer	Abdi Osman		
Description of project	The key objective of the proposed work is to simulate a multi-terminal Voltage Source Converter (VSC) HVDC link using a real time digital simulator (RTDS) in order to study its operation on the electricity transmission system. An RTDS is a powerful state of the art simulator that allows power system simulation of various power system components in real-time timescales. The use of an RTDS will allow for the technology to be modelled in significantly more detail and accuracy than available via software solutions such as PowerFactory, PSSE or PSCAD. RTDS systems are also capable of outputting analogue signals to allow for the testing of equipment such as protection relays etc. The simulation will fulfil the role of a phantom trial in accordance with National Grid's policy for the introduction of new technology. The work aims to demonstrate that a multi-terminal VSC HVDC system as proposed is feasible, to identify potential problems with application of the technology, areas of further research and to inform specifications. The use of the RTDS will allow for the simulation and evaluation of any converter topologies or control strategies that have been made public by suppliers or proposed by other parties. Further to the primary objective of this research is the added benefit of developing the UK research capability in the field of HVDC. It is the aim of industry and academia to establish significant expertise in HVDC in the UK in order to ensure that the rapid expansion of complex HVDC systems across the UK and Europe occurs as smoothly as possible. This project supports this aim and will be followed by further proposals in the future including the associated work at Cardiff University.		
Expenditure for financial year 12/13	Internal £54k External £10k Total £64k	Expenditure in previous (IFI) financial years	Internal £3k External £279k Total £282k
Total project costs (collaborative + external + [company])	£ 246k	Projected 2013/14 costs for National Grid	£0k
Technological area and/or issue addressed by project	In July 2009, the three Great Britain Transmission Licence holders supported by a Project Working Group published their report to the Electricity Networks Strategy Group (ENSG) on the strategic reinforcements required to facilitate connection of the generation mix to the GB transmission networks by 2020. The report presents generation and demand scenarios consistent with the EU target for 15% of energy to be produced from renewable sources by 2020 and identifies and evaluates a range of potential electricity transmission network solutions that would be required to accommodate these scenarios. Among the options currently under consideration is the use of a multi-terminal HVDC link to provide additional capacity across transmission boundaries in the onshore transmission system and potentially to be used in the connection of offshore generation. Such a multi-terminal HVDC link might prove to be the most overall economic and efficient solution		

	available when wider developments are taken into account. National Grid has not previously implemented VSC HVDC converters on the transmission system and no multi-terminal VSC HVDC system has been implemented anywhere in the world. The introduction of this technology on to the transmission system must be managed in a manner that takes due consideration of any potential technology risks.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		11	-2	4
Expected benefits of project	The main benefit of the proposed work is management of the risks associated with introducing new technology onto the electricity transmission system in accordance with National Grid policies. The work is essential in order that the use of multi-terminal VSC HVDC on the transmission system may be permitted under National Grid governance. The savings in deploying such a solution in preference to less economic and efficient options is likely to be more than £100M. In addition to the above, any problem in application of the technology which causes delayed commissioning of the HVDC link or interruption of its operation when in service will result in costs of the order of £5m per month being incurred in constraint costs alone. The proposed work will identify potential problems before contract placement and allow the above costs to be avoided. An additional benefit will be the development of capability in this field. Whilst the RTDS system will remain the property of the University of Birmingham, National Grid will continue to have access to it. It is also envisaged that as National Grid's HVDC R&D portfolio increases access will be provided to other R&D suppliers such as other universities who do not possess this modelling capability.			
Expected timescale of project	2 years	Duration of benefit once achieved	5 year	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£1706	
Potential for achieving expected benefits	The use of RTDS is well established in the area of HVDC technology and the simulation may be carried out with confidence. It is believed that multi-terminal VSC HVDC will be found to be feasible, but this requires to be demonstrated, hence this project. It is certain that learning points will emerge. Difficulty in obtaining precise details of converter structures and component parts is anticipated and where necessary a range of possible solutions will be studied. It is anticipated that models will be refined as new information becomes available.			
Project progress [Year to End of March 2013]	The work completed by the end of March 2013 include the following deliverables: Deliverable 1: Commissioning of two additional RTDS racks (July 2012). The work includes the integration of the two additional RTDS racks with the existing two racks in collaboration with the supplier.			

	Deliverable 2: Initial converter models complete (July 2012). **The work includes completion of initial detailed modular multilevel converter (MMC) models and description of the basic topologies and control functions. The deliverable was presented in the Month 3 review meeting.** **Deliverable 3: Multi-terminal (4-terminal) MMC VSC HVDC model complete (Oct 2012).** **The work includes completion of a Multi-terminal (4-terminal) MMC VSC HVDC and associated detailed control models.** **The control modes (PQ, P-Vac, Vdc-Q, Vac-f) at relevant terminals were demonstrated while potential coordination issues were identified.** **Deliverable 4: Control performance of multi-terminal MMC VSC HVDC (Feb 2013).** **Control performance of a multi-terminal MMC VSC HVDC were studied for the following special operational scenarios including:** — **Ramping of power** — **Power reversal, control and protection aspects** — **Connection and disconnection of offshore wind farm** — **Operation with intermittent wind generation.** **In addition, the detailed wind farm model and its integration with the multi-terminal MMC VSC HVDC were completed by the end of March 2013.**
Collaborative partners	
R&D provider	**University of Birmingham**

Project title	A Combined Approach to Wind Profile Prediction				
Project Engineer	David Lenaghan				
Description of project	The aim of this project is to develop efficient and effective algorithms for wind profile prediction based on synergies between the signal processing approach and the computational fluid dynamics approach. One of the main deliverables will be a PhD thesis which contains the source code and prediction methodology details.				
Expenditure for financial year 12/13	Internal £5k External £10k Total £14k		Expenditure in previous (IFI) financial years	Internal £3k External £11k Total £13k	
Total project costs (collaborative + external + [company])	£37k		Projected 2013/14 costs for National Grid	£10k	
Technological area and/or issue addressed by project	Wind profile (including speed and direction) prediction at different scales (short-term, mid-term and long-term) plays a crucial role for efficient operation of wind turbines and wind power prediction. This problem can be approached in two different ways: one is based on statistical signal processing techniques and both linear and nonlinear (such as artificial neural networks) models can be employed either separately or combined together for profile prediction; on the other hand, wind/atmospheric flow analysis is a classical problem in computational fluid dynamics (CFD) in applied mathematics, which employs various numerical methods and algorithms, although it is an extremely time-consuming process with high computational complexity. On the CFD side, in the simulation/prediction of the atmospheric flows on the surface, one particular difficult regime is the case with stable stratification. Stable stratification leads to internal gravity waves. The interaction between the waves and turbulence remains a challenge for the modelling of turbulent atmospheric flows. Among the various issues, an important one is how to accurately account for the incoming/outgoing waves in the boundary conditions. If not properly handled, artificial waves can be generated in the simulations, which could destabilize the simulations. On the other hand, the signal process methods developed in Electronic and Electrical Engineering (EEE) at the University of Sheffield are particularly suitable for capturing the wave components in a noisy signal. Therefore, the synergy between the two approaches can be particularly valuable for the simulation/prediction of wind profile/atmospheric flows.				
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score	
		4	-1	5	
Expected benefits of project	Increased forecasting accuracy which will have the consequent benefit of reducing the reserve requirement kept on the system due to the wind.				

Expected timescale of project	**2 years**	**Duration of benefit once achieved**	**8 year**
Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**-£26k**
Potential for achieving expected benefits	**Very likely. The proposed project is innovative and theoretically sound and promising. The University of Sheffield has academics with a track record in the work that they are doing and the initial student has a first class honours degree. The student has access to expertise from all departments within the University of Sheffield, also expertise from Imperial College London and John Hopkins University in the US through the collaboration work of the two project supervisors.**		
Project progress [Year to End of March 2013]	**September 2011 - The initial student from Sheffield has withdrawn. The project is therefore paused until a new PhD student is found.** **September 2012 – A new student has been found for this project. She has completed some initial reports and done a literature review and been put in touch with researchers at Reading University performing similar work.** **The student has created a power point presentation describing some of the areas of future work. Teleconferences take place every two weeks where progress is discussed and next steps decided upon.** **With the literature review complete, there will be areas of research that will come to light and be useful in a practical way. The work is being steered to have a practical focus and devise the tools and models to be utilized by National Grid to improve forecasting accuracy.**		
Collaborative partners			
R&D provider	**University of Sheffield**		

Project title	MI HVDC Cable LoadCycling (Load cycling and radial flow in mass impregnated HVDC Submarine cables)		
Project Engineer	**Gregory Tzemis**		
Description of project	**To determine what load conditions (power ratings and load patterns) typical high voltage direct current (HVDC) mass impregnated paper insulated cables can be subjected to without risking cavity-induced dielectric breakdowns during a cool-down period after a power reduction or turn-off.** **To establish an informal North Sea cable working group towards collaboration on HVDC link projects, potential sharing of spares holding and repair resources.** **Project Deliverables:** **Obtain a detailed physical understanding of the processes that lead to cavity formation and the importance of various operational, environmental and cable design parameters to these processes.** **Develop a numerical model that quantitatively describes the radial mass flow and cavity formation under load cycling.** **Determine the operational constraints for one or more HVDC subsea cables presently in service.**		
Expenditure for financial year 12/13	Internal £10k External £125k **Total £134k**	**Expenditure in previous (IFI) financial years**	**Internal £9k** **External £60k** Total £69k
Total project costs (collaborative + external + [company])	£1,867k	**Projected 2013/14 costs for National Grid**	**£140k**
Technological area and/or issue addressed by project	**HVDC mass impregnated (MI) cables have complicated stress processes that are particularly vulnerable in the cooling stages immediately associated with power reductions or emergency shut downs, especially when occurring during the delivery of short term overloads, however the behaviour of MI cables under different load conditions is not clearly understood. This knowledge would be of great benefit to Utilities.** **Mass impregnated HVDC subsea cable is state-of-the-art technology. The electrical insulation of such cables consists of paper impregnated with a high viscosity oil (the ”mass”), enclosed by a lead sheath that prevents water ingress.** **Recent installations operate at typically 400 - 450kV and have a continuous power rating per cable of up to more than 500MW. Two HVDC links are presently in operation between Norway and the European continent, and more are expected to come. In a future pan-European electrical power grid, subsea cables in the North Sea are expected to play a crucial role, both for exchanging power between the UK, Scandinavia and the European continent, and for transferring power generated in large off-shore wind farms.** **It is generally accepted that the cooling period after a power reduction or turn-off is the most critical part of the operation of subsea mass impregnated HVDC cable. Consequently, the power rating of such cables, both with regard to short-term overloads and on a continuous basis, is**		

	largely set by considering the risk of having a dielectric breakdown during a power reduction or turn-off. However, as will be described in some detail below, the behaviour of the cable insulation under different load conditions, and thereby the risk of having such breakdowns, is far from fully understood. Hence, it is reasonable to assume that the true capacity and operational flexibility this cable technology can offer are not fully exploited. **Ohmic loss in the conductor is the main source of heat generation in a loaded cable. Hence, the conductor will always be at a higher temperature than the surroundings, and there will always be a heat flow and an associated temperature gradient in the radial direction through the cable insulation.** **The thermal expansion coefficient of the mass impregnation is ten times that of paper. During load increase, the associated thermal expansion causes the volume of the insulation to increase and the lead sheath is inelastically deformed. If the elastic properties of the armouring combined with the external water pressure do not compress this volume sufficiently during cooling, cavities will form in the insulation. Moreover, the greater temperature reduction and thus a larger thermal contraction of the inner parts of the cable than of the outer parts, is also expected to contribute to cavity formation.** **These cavities greatly reduce the dielectric strength and may cause long breakdown channels extending tens of centimetres and even meters, in the axial direction.** **Moreover, thermal cycling may over time lead to a lasting and irreversible displacement of the mass impregnation. The inner insulation layers become depleted, while mass accumulates between the outer insulation layers and the lead sheath.** **The existing knowledge about the importance and significance of the various factors expected to influence on the cavity formation and their interaction is indeed limited, even though such relationships essentially determine the power rating and safe operational patterns for a subsea HVDC mass impregnated cable. In other words, subsea transmission systems are presently operated under constraints that probably are unnecessarily strict.**			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	Overall Project Score
		11	-3	**14**
Expected benefits of project	**This could allow enhanced use of existing interconnectors as well as better specification of future HVDC cable systems.** **An increase in operation flexibility of a few percent could greatly enhance National Grid's ability to reduce the constraint boundary where we have seen 2 incidences of the wind being turned off, costing the industry circa £800K and £1M respectively in the year 2011. The majority of this cost is in the last few percentage of supply removal meaning this project could potentially have savings in the region of £500k per year on constraints.** **Knowledge is applicable to existing HVDC Links such as BritNed and the French interconnector as well as for future HVDC Links such as the Western HVDC link and other potential offshore developments for which many MI HVDC cables would be required.**			

	The partnerships with the Norwegian and Dutch Utilities will allow the exchange of know how on an informal basis which, together with the working relationships, will be of benefit to future proposed links and the maintenance and operation of existing links.		
Expected timescale of project	4 years	**Duration of benefit once achieved**	**5 years**
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	**£536k**
Potential for achieving expected benefits	**The participants have a good track record and facilities leading to a strong likelihood of success to develop important knowledge.** **The test method carries some risks, but other partial discharge methods could be adopted, although this might impact in the programme.**		
Project progress [Year to End of March 2013]	The project has delivered an IEEE paper which has been accepted for publication in early 2014. This describes current knowledge of MI HVDC Cable Technology. Prototype **high voltage (HV)** bushings have been developed and proved to be free of discharge**. T**hese **will** allow application of HV AC signals to explore Partial Discharge in the **cables.** Some additional work has been completed exploring the migration of mineral oil, both radially and axially in the cables and this has had an impact on the spend profile, but the project is still within its budget. Project Management and Reporting have been to a high standard.		
Collaborative partners	**Sintef Energy and NTNU (Trondheim) via Consortium with Statnett & TenneT**		
R&D provider	**Sintef Energy and NTNU (Trondheim)**		

Project title	Multi-terminal VSC HVDC operation, control and ac system integration		
Project Engineer	**Paul Coventry**		
Description of project	**The objective of the project is to improve understanding of the problems of Voltage Sourced Converter (VSC) HVDC integration into the existing transmission system. The project aims to make progress in three related areas:** **1. Multi-terminal VSC HVDC operation;** **2. AC/DC VSC HVDC interaction – control and** **3. AC/DC VSC HVDC interaction – detailed model (fast transients).** **These areas have been identified as requiring to be addressed as part of the risk managed introduction of the technology onto the transmission system. The project will deliver reports on the results of studies and a documented set of models for use in National Grid's internal system studies. The work forms an essential step in being able to implement the technology on the transmission system.**		
Expenditure for financial year 11/12	Internal £13k External £131k **Total £143k**	**Expenditure in previous (IFI) financial years**	**Internal £4k** **External £74k** Total £78k
Total project costs (collaborative + external + [company])	£221k	**Projected 2013/14 costs for National Grid**	**£129k**
Technological area and/or issue addressed by project	**As a consequence of the European Union Renewable Energy Directive, the UK is committed to a target of more than 30% of electricity to be generated from renewable sources by 2020. The transmission reinforcements necessary to allow the EU 2020 renewable target and longer-term energy goals to be achieved in an effective and efficient manner were studied by the Electricity Networks Strategy Group (ENSG) and detailed in their report 'Our electricity transmission network: A vision for 2020'. It was recognised in the report that due to planning constraints and environmental concerns, traditional methods of enhancing system capacity can be difficult to achieve and consideration was given to employing the latest technology, especially where this would yield additional economic and/or environmental benefits. One such technology potentially contributing to the achievement of the above aims is Voltage Sourced Converter (VSC) HVDC transmission. Furthermore, VSC HVDC is, in principle, well suited to multi-terminal applications which would allow optimised designs integrating onshore and offshore networks to be achieved and such solutions are under consideration for the GB transmission system.** **However, while the technology is believed to be achievable, National Grid has not previously implemented VSC HVDC on the GB transmission system and multi-terminal VSC HVDC has not previously been implemented anywhere. It is essential, therefore that an adequate understanding of the application issues be developed.**		

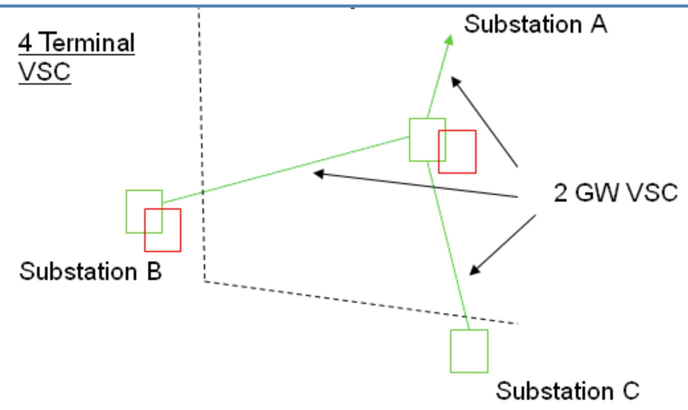


Figure 3. Example schematic for possible multi-terminal HVDC link to be studied(Red = AC, Green = HVDC)

The figure above outlines a possible layout of a multi-terminal HVDC link and is indicative of the type of system that may be studied. However, this work is not limited to embedded HVDC systems and multiterminal HVDC windfarm connections will also be studied in a range of configurations and topologies.

The work is complementary to the "Simulation of multi-terminal VSC HVDC system by means of real time digital simulator (RTDS)" at the University of Birmingham which is the subject of a separate IFI proposal. It is also proposed that all parties involved in this project work closely with National Grid engineers in order to ensure minimal duplication of effort and in order to ensure that the project delivers the best results and that these can be used immediately in modelling and network studies.

Type(s) of innovation involved	Significant	**Project Benefits Rating**	**Project Residual Risk**	Overall Project Score
		10	3	**7**

Expected benefits of project	**The proposed work forms part of the risk managed introduction of multi-terminal VSC HVDC on to the transmission system. VSC HVDC has not previously been implemented on the GB transmission system and multi-terminal VSC has not previously been implemented anywhere. It is essential, therefore, to understand how a multi-terminal VSC HVDC system would interact with the existing transmission system and how control of the different converters of a multi-terminal system would be coordinated. The proposed work is intended to identify application issues associated with the technology and allow control measures to be evaluated. Failure to identify and manage such issues ahead of commissioning might have severe implications for operation of the link. If delayed, commissioning or unavailability of the link pending a solution would result. Each month that the HVDC link is delayed could result in significant constraint costs being incurred. This project will help to ensure that all appropriate measures have been taken to avoid a delay in VSC projects.** **In addition to this, this project will help to inform National Grid policy regarding the construction and operation of multi-terminal HVDC systems (of which there may be many) that are connected to our system.**

Expected timescale of project	4 years	**Duration of benefit once achieved**	**1 year**

Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	**£59k**
Potential for achieving expected benefits	**The project is certain to increase understanding of the issues associated with application of a multi-terminal VSC HVDC system on the GB transmission system. There is a high likelihood that such studies will allow application issues to be identified, better understood and enable their mitigation to be evaluated.** **It is important that at all stages a close working relationship is maintained between National Grid engineers and University of Manchester researchers in order to ensure timely transfer of knowledge.**		
Project progress [Year to End of March 2013]	**Milestones previously achieved (March 2012)** • **Multi-terminal control review (report) – summary review of public domain information** • **Review of DIgSILENT PowerFactory capability for VSC-HVDC system modelling (3 reports – load-flow, short-circuit, transient studies).** • **Scenario review of offshore networks and modelling requirements** **New milestones March 2013:** • **Multi-terminal VSC-HVDC (MTDC) model developed in DIgSILENT PowerFactory along with study of control for MTDC according to a variety of different strategies (report and model). This model is now being modified and used to provide a review of the impact of different droop lines and control settings for one of the National Grid business groups (contact: Richard Poole). A linearized analysis methodology for the effects of various control schemes has been developed for steady-state operation describing system reference voltage deviation and deviation from nominal power due to the effects of power-voltage control-line settings (report).** • **GB network construction and MTDC integration model. A UK-like system model has been developed from Keith Bell's 29-bus UK-like load flow system. This has been integrated with a north-south VSC-HVDC link on the east coast and a variety of initial studies have been conducted.** • **POD Literature review. A review of public domain literature for Power Oscillation Damping (POD) has been carried out (report).** • **A review of system component modelling fidelity was undertaken detailing most of the main components in a VSC-HVDC system (report). A study on cables is being produced as part of a separately funded EPSRC project and will be submitted shortly.** • **GIC literature review. A review of public domain literature assessing the potential effects of Geomagnetically Induced Currents (GIC) on VSC-HVDC has been carried out (report).**		

Collaborative partners	
R&D provider	**University of Manchester**

Project title	Development of Advanced LCC HVDC Model for System Studies		
Project Engineer	Ziming Song		
Description of project	The objective of the project is to develop the PowerFactory Line-Commutated Converter (LCC) HVDC converter model for performing power flow studies and the network stability studies by National Grid engineers. The project aims to add the reactive power control, the filter switching and the converter transformer tap changes into the PowerFactory model. These areas have been identified as requiring to be addressed when the model is used to represent the thyristor based HVDC systems and operate not only at the DC system full rating but over a wide range of power transfer levels of the DC link. The project will deliver a model that can be integrated with any simplified circuits and the entire National Grid network model for power flow and stability studies. The work forms an essential step in developing National Grid's capability of network performances studies.		
Expenditure for financial year 11/12	Internal £9k External £10k Total £19k	Expenditure in previous (IFI) financial years	Internal £3k External £15k Total £18k
Total project costs (collaborative + external + [company])	£37k	Projected 2013/14 costs for National Grid	£0k
Technological area and/or issue addressed by project	As a consequence of the European Union Renewable Energy Directive, the UK is committed to a target of more than 30% of electricity to be generated from renewable sources by 2020. The transmission network reinforcements and expansion necessary to allow the EU 2020 renewable target and long-term energy goals to be achieved in an effective and efficient manner were studied by ENA's Electricity Network Strategy Group and detailed in their report "Our electricity transmission network: A vision for 2020". It was recognized in the report that due to planning constraints and environmental concerns, traditional methods of enhancing system capacity can be difficult to achieve and consideration was given to employing the latest technology, especially where this would yield additional economical and environment benefits. One such technology potentially contributing to the achievement of the above aims is HVDC transmission. The Western HVDC link uses the thyristor based AC/DC converter technology and was proposed to be built as a major link across the Anglo-Scottish border to increase the inter-area power transfer capability and eliminate the constraints currently imposed on the border transfer for stability reason. In addition, there are many more HVDC projects that are currently under consideration and require a model which can be used in simulation studies effectively, accurately and easily. National Grid has not previously implemented HVDC modelling in the old system analysis suites – Ella and others. The model provided by DIgSILENT in PowerFactory has been studied comprehensively and the results were reported in TR (E) 466 – Computer simulation Tests of HVDC converter model in DIgSILENT. One of the major short comings identified in the model is the lack of the representation of the reactive power control while the converter operation moves from one level to another. It is essential and urgent to		

	develop the reactive power control function and incorporate it into the current model for future use. The developed model will be crossed checked and verified by means of a real time digital simulator.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		9	-3	12
Expected benefits of project	It is essential to include the reactive power control, filter/capacitor bank switching and converter transformer tap change into the PowerFactory model. With these functions successfully developed, the PowerFactory model will be able to present the HVDC station control and the control of the reactive power with reference to active power flow. The model will comprehensively represent the HVDC operations over a range of conditions within the existing transmission system, one of major features required for the automation of a series of computer simulation studies, reducing the time. The proposed development is essential in the converter model for power flow studies in steady state conditions and stability studies during transient conditions. It will lay a foundation for the future development of the model to include the advanced control functions, if they are required. The estimate of savings through the use of this model against manpower spend to do the simulation studies is £160k.			
Expected timescale of project	1 Year	Duration of benefit once achieved	5 Years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£63k	
Potential for achieving expected benefits	The potential for achieving the expected benefits is high based on the detailed project proposal and a close co-operation between National Grid and the supplier, essential to ensure the project delivers exactly what is needed. In addition the supplier has many years experience of PowerFactory and has a test facility specifically for the HVDC studies.			
Project progress [Year to End of March 2013]	The activities for project progress from the collaborative partners, the University of Birmingham, are listed as follows: Jan 2012: References reading to build a deep understanding of LCC-HVDC models for operation and control in normal conditions and under disturbances; Feb 2012: Training for DIgSILENT PowerFactory 14.1 to get familiar with elements of LCC-HVDC models such as 6-pulse rectifier and inverter and AC filters, how to build LCC-HVDC models and carry out simulations for power flow and transient stability analysis. Feb 2012: First group meeting with collaborative partners from National Gird and at University of Birmingham to discuss about the key issues, the further work plans for Stage 1 based on the summary of the understanding of the LCC-HVDC systems and the work progress. Mar 2012: Building the Bipolar LCC-HVDC model for RMS-type power flow			

	analysis and stability analysis in DIgSILENT PowerFactory 14.1 for the requirements of research proposal. Mar 2012: Investigating the National Grid Bipolar LCC-HVDC model in DIgSILENT PowerFactory at National Grid and discussing the key issues of the further studies and the further work plans for Stage 2 and completing two tasks for Stage 1 as follows: • A review of the LCC HVDC model in PowerFactory 14.1 and providing an in-depth description of the model. • An investigation of the capabilities and limitations of the model running for root mean square (RMS) type power flow and stability studies. Mar 2012: Modifying the Bipolar LCC-HVDC model with functions similar to National Grid's model and validating its performances for RMS-type power flow analysis and stability analysis to meet the requirements for further tasks for Stage 2. Mar 2012: Carrying out simulations and completing rest of the tasks for Stage 1 listed as below: • Identifying the percent errors in V_{ac}, I_{ac} etc. when the model experiences unbalanced fault conditions. • Studying the reactive power flow of the converter under different operation modes and investigating the relationship of active and reactibve power over a range of power flows from 10 to 110 percent of the full rating. • Investigating the effects of a build-in transformer in comparison with an external transformer (tap-changing control is not considered at this stage). • Generalising the model for representing the systems having different ratings, such as 1000MW, 1500MW and 2000MW. Mar 2012: Investigating the feasibility of user-defined controllers using DIgSIELNT Simulation Language (DSL) and DIgSILENT Programming Language (DPL) to realise the automatic switch control of AC filter banks and tap-changing of built-in and external converter transformers for Bipolar LCC-HVDC model. Oct 2012 A workshop was held with National Grid on the progressive development and preliminary results. Nov 2012 The development work was completed. The model and the accompanying report were delivered to National Grid.
Collaborative partners	
R&D provider	The University of Birmingham

Project Title	Protection and Fault Handling in Offshore HVDC Grids		
Project Engineer	Ashish Bangar		
Description of project	The project will largely focus on offshore grids to target one of the thematic areas within energy systems. The primary objective of the project is to establish tools and guidelines to support the design of multi-terminal offshore HVDC grids in order to maximise system availability. Main focus will be on limiting the effects of failure and the risks associated to unexpected interaction between components. A collaborative research group is being established, made up of utilities, manufacturers and research bodies, to investigate the interaction of HVDC converters, DC and AC network components within an offshore transmission grid. The main focus will be on transient analysis and failure scenarios. Research methods include simulations (EMTP, PSCAD), laboratory validations and demonstrations, and real-time simulations (RTDS). In summary, the work will • Develop models of offshore grid components (cables, transformers, AC and DC breaker and HVDC converters) for electromagnetic transient studies. • Define guidelines to reduce the risk of unexpected interactions between components during normal and fault conditions. • Define strategies for protection and fault handling to improve the availability of the grid in case of failure. • Demonstrate the effectiveness of these tools with numerical simulations (PSCAD, EMTP), real time simulations (RTDS, Opal-RT) and experimental setup. • Expand the knowledge base on offshore grids.		
Expenditure for financial year	Internal £5k External £44k Total £49k	Expenditure in previous (IFI) financial years	Internal £0k External £0k Total £0k
Total project costs (collaborative + external + [company])	£2,500k	Projected 2013/14 costs for National Grid	£35K
Technological area and/or issue addressed by project	The transmission backbones for future offshore grids will rely on the HVDC technology since it represents the only viable candidate for transmission of high power with cables over long distances. Most of HVDC has been used mainly for point-to-point transmission with one sending and one receiving converter station. The need for integration of large scale renewable generation and the integration of markets has resulted in a demand for new transmission capacity and interconnectors. To meet this need, consideration is being given to applications of more multi-terminal or meshed HVDC grids. The future power system is going to be highly complex, integrating renewable generation, increasing usage of long cables and HVDC. Successful implementation will require		

	extensive computer simulations during all the planning and engineering phases. Existing simulation tools have limited accuracy for representing some critical components such as transformers and cables. The project will analyse phenomena like mutual interaction between converters, fault conditions and transient phenomena, as well as the possible interactions between AC and DC systems. This project will be linked to additional National Grid supported IFI projects in related areas with the University of Birmingham, Converteam (now part of GE), the University of Aberdeen and the University of Manchester.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	Overall Project Score
		12	-5	17
Expected benefits of project	A number of benefits are from the development of a coordinated offshore transmission network as compared to a point to point or radial network. These benefits can be categorised as follows: • Environmental and consenting benefits; • Improved management of valuable resources including land take, corridor routes, and manufacturing capability; • Reduced cost for UK consumer (capital cost reductions and also a reduction in operational costs such as maintenance costs and congestion management costs in relation to system operation); and • A flexible offshore transmission network that is better able to respond to future challenges. Business benefit will accrue through the attainment of knowledge, cross industry experience and establishing best practice in the field of modelling of offshore grid in the context of future networks. Taking a number of recent incidents into consideration it is very evident there is generally a shortage of information and perspective on this topic. Total potential cost savings associated with National Grid's coordinated strategy of £7 billion by 2030 have been identified, when compared with the development of the offshore transmission network on a radial basis. This work will help to facilitate the connection of £50bn of renewable generation (30GW) onto the network. Knowledge and modelling of protection and fault handling on this unprecedented design of the network is essential to understand the level and impact of transient voltages that will arise from these types of connections to renewable generation and designing solutions to mitigate or neutralise their occurrence. Failure to do this could, in the worst case, lead to substation equipment failure, loss of generation, loss of widespread parts of the DC network and a consequential reputational loss. This work will facilitate the network operability and reduce the impact of failures and installation costs. A conservative estimate is that this work could reduce coordinated strategy			

	installed costs by up to 0.5% equating to a potential saving of £35m although with uncertainty on the likelihood of success of the project. Improving the uncertainty around the extent of this cost would be established during the project. Avoidance of one failure on the future network has the potential to save costs of £5m in repairs once the network is delivered, this project is assumed to have a potential 10% impact on this repair cost. Additional savings may accrue through reduced reinforcement of the onshore transmission network. The consortium (SINTEF, NOWITECH, NTNU and RWTH Aachen University) has been formed with the support of the Norwegian Research Council; National Grid will leverage funding through access to a €2.5m research programme.		
Expected timescale of project	5 years	Duration of benefit once achieved	8 year
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£1,725,507
Potential for achieving expected benefits	The project is certain to increase understanding of the issues associated with HVDC grid and multi terminal VSC HVDC system. There is a high likelihood that such studies will develop better understanding of offshore network models, development of protection strategy and efficient transfer of power. The valuable experience gained during the pilot will help significantly to reduce risks during the enduring project roll out. There is a high uncertainty on the application of the project given the number of unknowns however the potential impact if successful is high (as in above benefit statement). In addition National Grid will have the opportunity to direct, to some degree, the scope and prioritisation of work. National Grid could also build on and accelerate research on topics identified as of particular relevance to National Grid.		
Project progress [Year to End of March 2013]	Project started in July 2012 and three project meetings have been held to date (kick off meeting May 2012, workshop and steering committee meeting Nov 2012 and steering committee meeting Feb 2013). A technical literature review and collection of models of offshore grid work is in the initial phase. SINTEF presented a strategy to develop the model and investigate/verify results.		
Collaborative partners	SINTEF, NOWITECH, NTNU & RWTH Aachen University Research council of Norway, Statnett, Statoil, NVE, Siemens, EDF, GE/Converteam, the University of Birmingham, the University of Aberdeen, the University of Manchester		
R&D provider	SINTEF, NOWITECH, NTNU & RWTH Aachen University		

Project Title	European FP7 Projects		
Project Engineer	Alex Carter, Parry Batth, Adam Green		
Description of project	This project consists of 3 European FP7 projects – Real Smart, iTesla and UltraWire. The overall scientific and technical aim of the REAL-SMART project is to take a pivotal role in the creation of technology for intelligent operation of wide-area AC transmission grids using emerging measurement technologies. The project integrates in-depth understanding of the operational issues with analysis of state-of-the-art measurements and first-principles physical knowledge to invent and develop tools that will be deployed in the field in case studies with the transmission operator partner. iTesla - With an increasingly complicated grid, studies and new techniques will be required to enable the operation of transmission system. This project aims to provide these initial studies and develop operational practise that can be used across the European transmission system operators (TSOs) The UltraWire project consists of 2 parts, firstly the Nano Carbon Enhance Materials (NCEM) consortium, where knowledge is shared between interested parties in the field of enhanced Nano Carbon materials. The members include industry & academia and aim to find applications and drivers for NCEM. The second part is the Euro FP7 project UltraWire, which NGET joined as a result of the NCEM consortium. Within NCEM, a demonstration of synthesis of wires was given by Dr Kosiol at University of Cambridge. This attracted large interest and the UltraWire project was developed. This project consists of a large consortium, of which NGET is one of the Industrial partners.		
Expenditure for financial year	Internal £0k External £35k	Expenditure in previous (IFI) financial years	Internal £10k External £5k

	Total £35k		Total £15
Total project costs (collaborative + external + [company])	>£5m	Projected 2013/14 costs for National Grid	£0
Technological area and/or issue addressed by project	REAL SMART: Electrical transmission and distribution in Europe is entering a period of significant renewal and technological change. Transmission grids such as the Nordic system, the National Grid in the UK and the UCTE system in continental Europe are accepting power injections from new and variable energy sources, especially from large-scale wind power generators, and will therefore face major future challenges in operation and control. Policy documents from the US DOE, EU and UCTE and the National Grid have highlighted (i) the need for improved grid infrastructure and advanced control technologies and (ii) the importance of emerging measurement-based technology in enhancing the stability and security of AC transmission in an increasingly complex operating environment. Changes happening in the process industries also have an impact on electrical supply. Sustainability, efficiency and maintenance considerations are leading to electric motors taking over from traditional gas turbine drivers for rotating machinery such as compressors. Understanding and managing the interface between these large and variable electrical loads and the transmission grid is of great interest for smooth operation of the transmission system. Trained, experienced and knowledgeable people are required to achieve the ambitious agenda for operation of the European electricity supply networks in the future. Meeting the target will require collaboration between academia and industry and people able to do creative research who are also trained to convert the technologies into industrial systems and products. The changed operating, business and technical environment in the industry requires new ways to monitor and manage system stability security and reliability. This proposal presents a balanced programme of applied R&D to address measurement based monitoring and management of the high voltage transmission grid.		

iTesla:

The pan European transmission grid will have to be reengineered progressively in order to accompany the electric system decarbonisation, shaped by a first set of intermediate targets in 2020. This long term transition will make transmission networks more and more complex with impacts on normal and emergency operations.

1.)Much larger power transfers over longer distances

2.) Predicting accurately the scheduling of power plants across Europe will become more difficult, which, in turn, will require conventional generators to balance the whole system.

3.) With the rapidly increasing penetration of renewable electricity generation and the difficulty to build new overhead power lines, each TSO in Europe will no longer be able to comply with the classical preventive N-1 security standards all year round.

4.) When operating a power system close to its stability limits, unstable dynamic phenomena may appear after a contingency. The standard static security assessment based on power flow calculations is not anymore sufficient.

Overall, transmission operators take margins (limits below the “true” physical limits) in their day-to-day decision making process, which ensure system security. The pan European system will be more and more stressed: it will become less and less possible to keep such margins safe. An improved assessment of the limits and of the distance to these limits is a prerequisite to avoid considering the system as unsafe and uncontrollable, even in “normal” operating conditions.

New concepts, methods and tools are therefore needed to define security limits and to quantify the distance between an operating point and the nearest security boundary: this requires building the most likely description of the pan European Transmission Network and developing a risk based security assessment accounting for the dynamic behaviour of the system. These needs are relevant at both the national and pan European level, with the pressing constraint of keeping any assessment as reliable as possible while system complexity keeps increasing. The resulting tools should then be accessible through a comprehensive tool box, shared and used by TSOs at ENTSO-E level and having three overarching functional goals.

UltraWire:

	The use of electrical energy continues to increase. Worldwide energy-related carbon dioxide emissions are projected to rise 43% between 2008 and 2035. Our future depends in many ways on increasing the efficiency of our energy usage. Today 8% of generated electricity is consumed in resistive losses, in the distribution network, within the electrical devices employed by end-users and in the transmission network. The large majority of these losses occur in copper-based subsystems including wiring, motors and transformers. Increasing the electrical conductivity of copper-based materials can address reducing losses across the large majority of these electrical uses. It is a potential step-change for society. Countries and companies that develop the manufacturing technology for high, room-temperature conductivity of copper will be able to drive value into society and create new jobs. This new manufacturing technology generates value beyond simply cost-reducing manufacturing processes, which continue to drive jobs from Europe to Asia. With the current drain on Copper resources globally, using Copper in the current demands makes this metal an unsustainable commodity. This project is looking to reduce the amount of copper needed to produce a conductor. This project describes the scientific development and pilot-fabrication of electrical wire made from ultra conductive copper ("UltraWire"), an advanced copper-carbon nanocomposite material. Wire is the most common form in which copper carries electrical energy today, and this is the most useful form for immediate take-up by the energy industry. The project brings factory processes and science together using leading European universities and large companies from the European copper, cable and manufacturing equipment industries.			
Type(s) of innovation involved	Significant	Project Benefits Rating Varies for projects	Project Residual Risk Varies for projects	Overall Project Score Varies for projects
Expected benefits of project	REAL SMART: For very low cost National Grid can have exposure to the latest thinking surrounding how infrastructure should be best reinforced and advances in control technology, as well as being kept informed on the important area of measurement-based technology enabling stability and security of the AC			

	transmission system in an increasing complex environment. **The three research themes of this project align with National Grid's views and concerns of the future. Providing knowledge in these areas can assist in avoiding misinformed investments resulting in stranded assets. Also ensuring the correct measures are taken to enable the continuing security of supply that the UK currently experiences.** **iTesla:** **This project is aimed at the changes that will arise on the networks in meeting the intermediate steps of 2020 Climate Change targets. National Grid will be exposed to the risks outlined above. This project aims to provide a toolbox of operational practise to mitigate these risks. In order for National Grid to meet the 2020 targets and continue to supply the security of supply the UK currently experiences it is vital that these areas are researched.** **UltraWire:** **If successful, there is a potential to up rate circuits where there are overhead line constraints. As the behaviour of the copper-carbon nanotube (Cu-CNT) conductor is significantly different to the conductors currently on the NGET system, it is believed that up rating is a viable option. The Cu-CNT conductor decreases in length when the temperature increases; therefore having implications on sag when increased load is on the circuit. However this would have to be considered as part of a scheme after the project has delivered.**

Expected timescale of project	**3-5 years**	**Duration of benefit once achieved**	**Ongoing**

Probability of success	**60%**	**Project NPV = (PV benefits – PV costs) x probability of success**	**Varies for projects**
Potential for achieving expected benefits	**REAL SMART:** **The consortium is well managed and well supported by a range of members from Utility Companies, suppliers and academic institutes; there is sufficient output form the work streams demonstrating progress towards successful outcome.** **iTesla:** **This consortium consists of 19 different institutes all keenly aware of the issues surrounding the transmission of electricity. This is a European centric problem due to the high population and unavailability of land.** **The project proposal compiled by the consortium has the highest risk of failure at 30% so the project committee give a high percentage chance of success.** **UltraWire:** **Thi sis a very strong consortium of members in the FP7 proposal, with a good balance between industry and academia. The current state of this technology is at a fairly advanced state, in that the University of Cambridge has developed a technique for producing a continuous length of wire. This initially seemed to be the major obstacle to the Cu-CNT challenge. As a result, this project is looking at up scaling the process, and addressing the key industry issues. In theory, this should not pose too much of a problem, so predicted success is initially high, however, as with all research based projects, there is potential to not deliver on the desired targets.**		

Project progress	**REAL SMART:**
[Year to End of March 2013]	**Following the two international academic researchers spending 3 month placements at the electricity network control centre (ENCC), ie Jukka Turunen from Aalto University, Helsinki Prof Herwig Renner from Technical University Graz, Austria, have completed their project reports which provide some useful insight for National Grid to follow up in enhancing National Grid's inhouse modelling and monitoring capabilities.** **Their work proved invaluable in being able to compare historic and current measurements and the corresponding analysis techniques with modelled results. It also gave a useful overview of the real system issues and has provided a very useful start to the project.** **The two days project meeting at Krakow was useful and both Jukka and Herwig had presented their findings at National Grid and presented their report this year.** **The work of particular relevance to National Grid includes probabilistic planning of offshore wind and subsynchronous resonance (SSR) detection on generating plant proposed by GE.** **There are six work streams in the Consortium and the level of participation varies depending on the relevance of the work to National Grid's business. These work streams are as follows:** **WP1- Network modelling and control to enhance power system security.** **WP2 – convert real time WAM data to informative information.** **WP3 – convert historical WAM data into system operation and performance.** **WP5 - Quantifying dynamic. impact of Wind generation on the Grid** **WP6 - Probabilistic planning methods for integration**

of large scale of wind generation.

There have been conferences to attend, such as the Real-Smart Mini-Conference in Baden, hosted by ABB Corporate Research Centre. The objective of the mini conference is to provide a forum for people interested in wide-area monitoring and control technology and its applications to meet and discuss. Industry and university experts will share their experiences in the conference presentation session and the latest research results from the REAL-SMART project will be reported in a poster session. The poster session is also open for any participant who wants to present a poster in a relevant area.
The speaker list includes industry specialists from power utilities as well as vendors and universities. Topics include:

- Utility experience with WAMCP technology.
- Cybersecurity challenges in networked control and monitoring systems.
- Challenges related to power system dynamics that utilities see today and foresee for the future.
- New developments in algorithms and methodologies for monitoring and controlling power system dynamics using WAMCP.

iTesla:

The first step of the project was to collect the expectations of the iTesla TSOs about system security assessment. A public deliverable provides a synthesis of this work and served as an input for the development of the functional specifications of the iTesla toolbox. The functional architecture of the iTesla toolbox is based on complementary interactions between on-line and off-line analyses.

The project aims to address in a single framework the challenges of dimensionality (pan-European grid scale), online performances (over a sliding time window from real-time up to two days ahead), consideration of uncertainties (intermittent generation) and dynamic constraints, and determination

of control actions. In order to achieve these performances, which are not compatible with a purely online analysis due to the very high computational requirements, an integrated offline/online methodology has been proposed. The rationale is to exploit online, the results of extensive offline analyses, within a suitable contingency filtering scheme. The deliverable D5.1 presents the methodology of the online security assessment and in particular, the two steps of the contingency filtering: a first step with active variables only (Worst Case approach in DC approximation) taking into account off-line security rules and preventive and corrective actions available to the operator, which allows to keep only the contingencies that require actions from the operator, and a second step taking into account off-line security rules including active and reactive variables, which allows, by sampling, to generate pre-contingency states that will be used as input data for further detailed analyses.

In parallel, several tasks have been launched to design and prototype the off-line analyses which aim to provide security rules by means of Monte Carlo simulations: definition of the methodology for sampling of stochastic variables (intermittent generation), building of the starting points for the time

domain simulations, classification of the system states based on the outcomes of these simulations and finally, extraction of the desired off-line screening rules. In addition, various data mining algorithms, needed both in the online and offline analyses, have been specified and prototyped.

Several use cases have been chosen in view of the global validation of the iTesla toolbox (public deliverable D1.4). These use cases will enable testing the main functionalities of the iTesla toolbox on different systems and in different operating conditions.

The main features of the IT architecture of the toolbox are defined in deliverable D1.3, including a description of the different computation modules, requirements regarding computation performances and data exchanges, benchmarks of different data mining solutions, and recommendations regarding process management, access to supercomputing environments, data management and storage solutions for the different kinds of data handled in iTesla.

The implementation of the proposed IT solution for data management has started (i.e. internal data model, import and export conversion tools between external and internal data formats, databases for dynamic data and for data mining). The public deliverable D2.1 provides the future users with a list of 17 recommendations concerning data needed in order to use the iTesla toolbox efficiently. And finally, the public deliverable D3.1 presents a general framework for validation of dynamic models, composed of four different stages. Stage 1 is dedicated to the definition of performance indicators to aid in model validation, stage 2 aims to figure out the discrepancies between a simulated model and its corresponding measurements, stage 3 is devoted to calibration of the model and finally, stage 4 provides recommendations for model updates. A priority list of

	models to be validated has been defined and a software architecture for model validation has been proposed and tested. **UltraWire:** The UltraWire project itself has not started this year. It is not due to start until October 2013. The initial costs with this part of the project are associated with the NCEM membership fee, travel to conferences, and legal charges associated with the UltraWire contract.
Collaborative partners	Multiple (>25)
R&D provider	European Commission FP7 Project