Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

NIA Project Registration and PEA Document

Date of Submission

Mar 2015

Project Reference Number

NIA_NGET0157

Project Registration

Project Title

EPRI Research Collaboration on Substations

Project Reference Number

NIA_NGET0157

Project Licensee(s)

National Energy System Operator

Project Start

January 2014

Project Duration

1 year and 7 months

Nominated Project Contact(s)

Iliana Portugues

Project Budget

£2,100,000.00

Summary

Transformer Life Management

(a) Maximising the diagnostic value of DGA through newgases

(b) Novel Sensor for Transformer Diagnostics

(c) The Copper Book (EPRI Power Transformer Guidebook)

(d) Transformer Remaining Life Research – NewMarkers

(e) Dissolved Gas Analysis Guide

(f) Transformer Forensics Database

Protection and Control

(a) Using Protective Relays for Condition Assessment: Catalogue the Enabling Technologies.

(b) Industry-wide Relay Performance Database: Data Format and Relay Performance Analysis.

(c) Standard-based Configuration Management for Protection & Control Systems.

SF6 Management and Gas Insulated Substations

Research on Sulphur hexafluoride (SF6) for breakers and Gas Insulated Substations / Gas Insulated Lines is focused on improving handling, enhanced diagnostics and reducing leaks. This project looks at the following areas:

1) Leak reduction technologies (both for sealing and for high sensitivity leak detection) are thus important to understand and effectively apply.

2) Research on diagnostics focuses on both gas analysis techniques and on partial discharge techniques (especially for GIS/GIL). Improved diagnostics remain vital since failure prevention of this highly critical equipment can significantly improve the reliability of electricity supply.

3) Research on handling issues such as live filling play an important role in increased worker safety.

Nominated Contact Email Address(es)

box.so.innovation@nationalgrid.com

Problem Being Solved

The electricity industry faces challenges that National Grid recognises are more cost-effectively and efficiently dealt with through international collaboration initiatives. In particular, challenges whose solutions require statistically diverse data sets and/or significant trialling and testing in different environments, under various conditions and/or diverse ways.

The Electric Power Research Institute (EPRI), with its wide international membership, is one of the routes through which these initiatives can be delivered and stakeholder value maximised. This approach of managing collaborative projects is beneficial to National Grid and our customers, providing valuable information, learning and knowledge, which would be more expensive to formulate on an individual basis.

In 2014, a benchmarking exercise by National Grid has determined the largest leverage within Substations for the UK consumer is achieved through involvement in both the transformers, SF6 management and the protection and control programmes.

Method(s)

Transformer Life Management

The transformer programme is looking at five themes to improve the knowledge and methodology for managing these assets:

1. Developing novel optical sensors and analytics to determine the condition and deterioration curves of the assets.
2. Collating worldwide knowledge and experience.
3. Understanding root-cause of failure and ageing mechanisms through forensic studies.
4. Developing improved methods for end-of-life estimation.
5. Reducing transformer failures through new markers for dissolved gas analysis (DGA).

Protection and Control

The focus of this research project is on three broad themes:

1. Identifying enabling technologies and developing new approaches to use protective relays for condition assessment;
2. Applying standard-based approaches to improve configuration management for relay settings and associated documentation;
3. Developing industry wide relay performance database to support relay fleet and asset management.

SF6 Management and Gas Insulated Substations

The SF6 research project is looking at several themes delivered through two main routes:

1. Scaled laboratory testing and field trials at one substation
2. Engagement in industry, academic, and regulatory groups to understand the issues

Scope

Transformer Life Management

(a) Maximising the diagnostic value of DGA through newgases

This project improves the power of DGA analysis through identification of new chemicals that assist in DGA interpretation. In parallel the research is exploring emerging on-line DGA technologies through the application of test protocols that simulate a wide range of repeatable field conditions. This task sets out to develop the test protocols and the experimental setups. This task explores the new technologies and reports back the data. The research results will help National Grid and similar electricity utilities better assess risk and improve the specification of technologies to meet our unique monitoring needs.

(b) Novel Sensor for Transformer Diagnostics

Under this topic work is being conducted on two sensors:

1. Optical Hydrogen Sensor for Transformers: This research addresses the need for highly robust transformer sensors – where the sensor ideally lasts as long as the transformer. Optical sensors using robust fibers provide promise for robust and low-cost detection. Efforts are focused on detection of Hydrogen dissolved in the oil. Hydrogen provides an early warning for many failure modes in transformers and was thus selected as the first sensor for research. A laboratory-grade prototype will be developed which will aim to detect down to 400ppm with a response time of 20h.
2. Optical Acetylene Sensor for bushings: Optical sensor research is showing promise for detection of the presence of low levels of acetylene through a sight-glass. This advance will allow for the improved assessment of the condition of bushings without the need to take a sample of oil. The proposed optical system may even be able to interrogate the oil through the sightglass from ground-level, thus avoiding an outage. If successful, the research will significantly aid in preventing in-service failures of bushings. This project will trial a laboratory system to determine the viability of further work.
3. Laser Vibrometer for acoustic emission detection: The vibrometer technology is being adapted from applications in other industries (civil and transportation). This research will focus on proving the capabilities in the test laboratory and developing the data processing approach best suited for signal analysis from substation components (Phase Resolved Partial Discharge Analysis). If time permits, field trials will be conducted.

(c) The Copper Book (EPRI Power Transformer Guidebook)

This project will develop a comprehensive transformer reference book that includes all aspects of transformer operation, maintenance, procurement and life-cycle management – each year it is kept current with evolving technologies and standards. It is written from the perspective of a utility engineer and addresses all phases of a transformer. The Copper Book serves as a valuable training aid and reference and guides engineers through case studies of common calculations necessary for transformer specification and management. In 2014 the aim is to advance the development in the area of diagnostic technologies and Chapter 8 of the Copper Book.

(d) Transformer Remaining Life Research – NewMarkers

Improving the accuracy of transformer life estimates offers significant reliability and financial benefits in managing aging transformer fleets. In earlier studies, research has identified promising new approaches to more accurate life assessment by tracking the behavior of new chemical markers (and marker ratios) in transformer oil. The approaches have worked well in accelerated-aging laboratory tests. In 2014, field testing in various utility substations will help validate the results. The research will lead to an Application Guide for assessment of transformer end of life.

(e) Dissolved Gas Analysis Guide

In 2014, research will focus on the development of a standalone DGA (dissolved gas analysis) guide for transformers and cables, in particular concentrating in the area of interpretation.

(f) Transformer Forensics Database

This research is examining retired transformers and relating the evidence to both historic transformer operations and diagnostics data. The resulting forensics library will provide National Grid with new insights into likely end-of-life scenarios for the increasing population of aging transformers. The information also provides helpful insights into the effectiveness of diagnostics since the diagnostic predictions can be compared with the actual internal condition. The collaboration with multiple utilities across the world allows the more rapid growth of this database.

Protection and Control

(a) *Using Protective Relays for Condition Assessment: Catalogue the Enabling Technologies.*

Modern protection, control and data acquisition technologies have the capabilities of self-monitoring, self-diagnosis, event capturing and alarming for failures. Microprocessor relays can monitor and diagnose the majority of its internal components, current and voltage sensing devices, tripping circuitry and data communication channels. These capabilities can be used to develop the new condition based protection system maintenance program. The objective of this proposed research task is to increase awareness and enhance

understanding of such enabling technologies, assess their effectiveness in a laboratory environment and provide utilities with selection and application guidance that can be applied in engineering standards and design specifications.

(b) *Industry-wide Relay Performance Database: Data Format and Relay Performance Analysis.*

To support utilities on relay fleet/asset management decisions, a collaborative effort is needed to gather significant relay operation, maintenance, and failure data in order to draw statistically valid conclusions on aging models and life expectancies for each type of relay fleet. This task will develop a standardized format for relay performance data to facilitate the data gathering, sharing, and analysis. This will be done through working with other utilities to gather sample data and validate the usefulness of the proposed format; use the sample data to demo relay aging models as well as other possible analysis, such as performance based or reliability-centred maintenance approaches.

(c) Standard-based Configuration Management for Protection & Control Systems.

Configuration Management (CM) consists of a collection of principles, processes and methodologies for managing configurable parameter and associated documentation in complex systems. The industry CM standards, such as ANSI/EIA-649, are well established and widely adopted by military, information technology and many other industries. For protection and control (P&C) system, a large amount of correlated configuration information and files needs to be tightly managed for its consistence and accuracy. Such information includes engineering design and drawings, protection calculation and relay settings, relay files and firmware, testing and maintenance records. A well-established CM system can ensure that the P&C configuration information and any changes to that information are systematically identified, approved, verified, and recorded in a sufficient detail throughout the system lifecycle; and also ensure that P&C configuration information conforms to functional requirements, P&C documentation matches the actual relay status in the field. This work will review industry CM standards and good CM practices from other industries with the objective to create a benchmark model that can be adopted or tailored specifically for P&C systems. Then, the benchmark model will be used to compare existing utility practices to identify the potential gaps or needs for improvement. The research work will also evaluate CM tools and develop applicable templates to assist utilities in the implementation of CM. The ultimate outcome from the configuration management research will assist utilities in moving towards standardized P&C design, automated processes such as protection setting verification, and maintaining good documentation and record keeping.

SF6 Management and Gas Insulated Substations

Research on Sulphur hexafluoride (SF6) for breakers and Gas Insulated Substations / Gas Insulated Lines is focused on improving handling, enhanced diagnostics and reducing leaks. This project looks at the following areas:

1) Leak reduction technologies (both for sealing and for high sensitivity leak detection) are thus important to understand and effectively apply.

2) Research on diagnostics focuses on both gas analysis techniques and on partial discharge techniques (especially for GIS/GIL). Improved diagnostics remain vital since failure prevention of this highly critical equipment can significantly improve the reliability of electricity supply.

3) Research on handling issues such as live filling play an important role in increased worker safety.

Objective(s)

Transformer Life Management

(a) Maximising the diagnostic value of DGA through newgases:

Develop new markers to better assess transformer risk of failure. Deliver a methodology to guide National Grid to apply these new markers. In addition, gather data on on-line DGA technologies and deliver data sets to allow for effective specification of DGA technologies to match the various situations and requirements.

(b) Novel Sensor for Transformer Diagnostics

The objective is to deliver optical technologies to provide non-contact diagnosis of energized bushings. Bushing failures can result in destruction of the associated transformer. Failures can also pose a health and safety risk. The objective is to assess bushing condition from a safe distance.

(c) *The Copper Book (EPRI Power Transformer Guidebook)*

The objective is to provide a regularly updated comprehensive guidebook on transformer life managementt.

(d) *Transformer Remaining Life Research – NewMarkers*

The objective is to provide a methodology on how better to assess transformer remaining life. It will also produce guidelines to help National Grid request a set of specific analyses from laboratories and effectively interpret the results.

(e) Dissolved Gas Analysis Guide

The objective is to provide a stand-alone, comprehensive guide on DGA (dissolved gas analysis) for power transformers – including guidance on specification of on-line analysis.

(f) Transformer Forensics Database

The objective is to deliver a database on forensic teardowns and the diagnostic results – allowing analysis on how diagnostic predictions aligned with actual conditions.

Protection & Control

Relay mal-operations can adversely impact system operation and disrupt electric service. This project aims to develop new methodologies, processes, and tools to assist utilities in the efforts of reducing complexity, human error and cost in protection system maintenance and asset management, prevention of relay miss-operations through effective configuration management processes, improving reliability and sustainability of utility industry's mission-critical protection and control infrastructure.

SF6 Management and Gas Insulated Substations

Research on Sulphur hexafluoride (SF6) for breakers and GIS/GIL is focused on improving handling, enhanced diagnostics and reducing leaks. It does so delivering the following objectives:

- Leak reduction technologies (both for sealing and for high sensitivity leak detection)
- Research on diagnostics focusing on both gas analysis techniques and on partial discharge techniques (especially for GIS/GIL).
- Improved diagnostics to significantly improve the reliability of electricity supply.
- Research on handling issues such as live filling for increased worker safety.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

Specific outputs for 2014, Transformer Life Management include:

- Report reviewing how diagnostic value of DGA through new gases may be maximised.
- Latest technology developments updated in the 2014 version of the Copper Book, a power transformer guidebook.
- Report reviewing new markers for the determination of transformer remaining life.
- Guidance on how to best to use dissolved gas analysis in transformers.
- Report detailing the output from the development and testing of novel sensors for transformer diagnostics.
- Software database with all transformer forensic studies done to-date and new data fields.

Specific outputs for 2014, Protection and Control include:

- Industry wide Performance Database for Protective Relays.
- Application Guidelines of Configuration Management for Protection and Control Systems.
- Technologies and Application Guidelines for Condition Based Protection System Maintenance.

Specific outputs for 2014, SF6 Management and Gas Insulated Substations include:

- Technical report detailing output of trials of SF6 Capture Technologies at Littlebrook substations.
- Technical report describing Alternatives to SF6 Technology in Power Delivery: Status of Research
- Gas Insulated Substations and Lines Guidebook detailing the whole life-cycle of SF6, GIS and GIL and specifically determining the following areas:
  - Top 4 Degradation Mechanisms and Potential Failure Modes
  - Aging, Corrosion, or Improperly Maintained Components of Switching Device Mechanism

- Deterioration (Corrosion) of Flanges and O-rings
- Tracking on the Surface of Spacers
- Excessive Thermal Overload Operation of GIS Equipment

Project Partners and External Funding

n/a

Potential for New Learning

n/a

Scale of Project

These projects are predominantly laboratory or desk based projects, with a minimal amount of site trials as required and as such there is no scope to reduce the scale of the projects any further.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

The research undertaken in the EPRI Substations programme is predominantly carried out in the UK and the US, although the programme also reviews the latest research from across the world.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

The total indicative NGET NIA expenditure for 2014 is £220,000.

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

n/a

How the Project has potential to benefit consumer in vulnerable situations:

n/a

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

Each project will have different financial savings based on the outcomes and potential benefits gained. Each EPRI programme that National Grid joins has been through three stages of review that consider the potential to deliver financial benefits.

In the first instance, within EPRI's governance, the Research Advisory Committee provides guidance on policies and issues that impact the power industry to inform the content of the research programmes.

Within National Grid, the Technical Leader for each aspect of the GB Transmission Network undertakes a review of the proposed EPRI programme relevant to their technical expertise and responsibilities and evaluates which provide potential value from a GB perspective as part of an annual review of which programmes to participate in.

The three projects, Protection and Control, SF6 Management and Transformer Life Management projects are expected to generate valuable learning which can improve and maintain the reliability of the system.

Please provide a calculation of the expected benefits the Solution

Not required for research projects.

Please provide an estimate of how replicable the Method is across GB

Protection and Control , SF6 and power transformers are present at all substations throughout the transmission and distribution networks.

Please provide an outline of the costs of rolling out the Method across GB.

The direct cost of making a policy or procedure change could range from as little as ten thousand to hundreds of thousands of pounds depending on the complexity of the change implications. The wider cost implications arising from such changes will be dependent on the specific outcomes generated from the project and typically will be subject to further stages of demonstration prior to roll out. Further information regarding roll out costs can be provided prior to demonstration stage.

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

☑ A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).

☐ A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)

☐ A specific novel operational practice directly related to the operation of the Network Licensees system

☐ A specific novel commercial arrangement

RIIO-2 Projects

☐ A specific piece of new equipment (including monitoring, control and communications systems and software)

☐ A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven

☐ A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)

☐ A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology

☐ A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution

☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

All GB electricity licensees own and manage substations containing power transformers and protection and control and several have assets containing SF6. They all face similar challenges around estimating remaining transformer life and minimising the risks of mal-operation of protection and control systems

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

n/a

☑ Has the Potential to Develop Learning That Can be Applied by all Relevant Network Licensees

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

n/a

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

n/a

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

n/a

Relevant Foreground IPR

n/a

Data Access Details

n/a

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

n/a

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

n/a

This project has been approved by a senior member of staff

☑ Yes