NIA Project Registration and PEA Document

Date of Submission

Sep 2016

Project Reference Number

NIA_NGET0195

Project Registration

Project Title

EPRI Research Collaboration on Substations 2016 (P37)

Project Reference Number

NIA_NGET0195

Project Licensee(s)

National Grid Electricity Transmission

Project Start

October 2016

Project Duration

0 years and 7 months

Nominated Project Contact(s)

Gordon Wilson

Project Budget

£1,215,139.00

Summary

EPRI research projects span across multiple years. Because of this approach, not all of the deliverables for P37 will be realised at the end of 2016. Nevertheless, there is scope for the delivery of a number of valuable outputs, reports and guidance documents in 2016.

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Problem Being Solved

National Grid recognises that the challenges faced by the electricity industry can be more efficiently and cost-effectively addressed when approached through international collaboration initiatives. It is particularly useful when addressing challenges where the 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, thereby maximising stakeholder value. The approach of managing collaborative projects within an internationally driven research and development initiative is beneficial to National Grid and consumers alike, because it provides valuable information, learning and knowledge that would be considerably more expensive if approached on an individual basis.

This project aims to address issues associated with three elements of substation plant:

1. Transformer life management, will address key issues including transformer diagnostics, condition and ageing assessments and life extension
2. SF6 management and Gas Insulated Substations (GIS) aims to help reduce maintenance costs and uncertainties, minimize SF6 emissions through the application of new technology, and improve life-cycle management
3. Risk based equipment asset management that conducts research with the goal of providing continually improved risk-based decision-support methodologies for substation equipment asset managers.

Following a benchmarking exercise in 2015, National Grid determined that within EPRIs Substations Programme 37 (P37) the largest leverage for the UK consumer can be achieved through involvement in specific areas of research; transformers (P37.101), SF6 (P37.108), and asset management (P37.111). The three areas have work-streams that span across multiple years. Consequently, this project will benefit National Grid and our stakeholders by continuing to deliver the valuable research and development activities of P37 into 2016.

Method(s)

P37.101 - Transformer Life Management
The transformer project is looking at seven themes to improve the knowledge and methodology for managing transformer assets. These will be delivered through:

- Collating worldwide knowledge and experience
- Researching and developing new technologies with academic organisations and research institutes – and deploying the recent successes in the laboratory in field trials in substations
- Computer modelling of scenarios and risk
- Substation trials of technologies
- Understanding root-cause of failure and ageing mechanisms through forensic studies
- Developing software algorithms and comparing them with models and case-studies.

P37. 108 - SF6 Management and Gas Insulated Substations
The SF6 research project is looking at several themes delivered through different routes in 2016:

- Research into SF6 leak sealing and detection technologies
- Full-sized testing at the EPRI Charlotte Laboratory
- Scaled laboratory testing.

P37.111 - Risk Based Substation Equipment Asset Management
This project conducts research with the goal of providing continually improved risk-based decision-support methodologies for substation equipment asset managers. It envisions that the developments will lead to an integrated framework for asset risk assessment, mitigation, and performance improvement. Developments in risk-based fleet management are addressed through:

- Asset characterizstion and performance information (also known as asset registries)
- Industry wide equipment performance and failure database and analytics
- Asset health algorithms and software
- Evaluation of dissolved gas in oil analysis (DGOA) analytics
- Triggers/alarms for maintenance actions
- Substation equipment asset management and maintenance practices.

Scope

EPRI research projects span across multiple years. Because of this approach, not all of the deliverables for P37 will be realised at the end of 2016. Nevertheless, there is scope for the delivery of a number of valuable outputs, reports and guidance documents in 2016. The full scope of research within each work-stream for 2016 is listed below.

P37.101 - Transformer Life Management
The transformer programme develops new tools and knowledge to help utilities anticipate and prevent failures in transformers, extend transformer life and develop and retain key expertise. With the increasing need for maximising the use of transformers while maintaining the same levels of reliability, managing ageing assets is a critical issue. This project addresses these key issues including transformer diagnostics, condition and ageing assessments and life extension. It does this through seven activities:

1. Transformer On-line Monitoring Technologies
Technology approaches to on-line gas analysis will continue from previous years to be researched, and in 2016 the extension in scope will be to include climate control to the tests using the research transformer. The expanded control will allow for simulation of a wider range of field-typical conditions. Two of these technologies will be tested on a full size transformer at the EPRI Lenox laboratory; one will undergo full site trials.

2. Novel Sensor Development
This work package will research new sensors for assessing the condition of a transformer. In 2016 research will continue to build

on the success in developing a stand-off laser detection system for quantification of the acetylene in bushings through the sight-glass. The advance is allowing for risk assessment of bushings without an outage.

3. EPRI Power Transformer Guidebook

This project will develop improved knowledge in the area of technological advances. The development of the guidebook built upon, year on year. In 2016 the Guidebook will expand the material on failure and event investigation and transformer asset management.

4. Improved accuracy of transformer remaining life estimation

This work package will continue to research the dynamic behaviour of new chemical markers in oil and whether it has the potential for improving transformer life estimates.

5. Transformer life extension

This work package has developed a novel approach to reducing the moisture in a transformer without cartridge replacements – which will, in turn, extend the transformer life. A new improved prototype (V2) has been designed and built, and in 2016 the work package will perform field demonstrations of the improved prototype in two substations in the field.

6. Transformer forensics – linking diagnostics and maintenance with true internal condition

This work package examines retired or failed transformers and relates the evidence to both historic transformer operations and diagnostics data. As of 2016 there are 20 detailed forensic study reports within the library.

7. Transformer ratings

In this work package the existing EPRI software tool for calculating transformer rating will be enhanced to allow easy rating, of not only the transformer but the entire circuit. The new overall package is named TRW (Transmission Ratings Workstation) and the BETA will be released in 2016.

P37. 108 - SF6 Management and Gas Insulated Substations

The SF6 and Gas Insulated Substations program is helping utilities reduce maintenance costs and uncertainties, minimize SF6 emissions through the application of new technology, and improve GIS and GIL life-cycle management through the following:

- Investigating more effective methods for locating and repairing SF6 leaks

- Developing a system for capturing SF6 when in-service repair is not viable

- Developing and documenting methodologies for accurately capturing SF6 data for regulatory reporting.

- Developing a fleet management approach for optimal decisions regarding new investment, maintenance, repair, and replacement of components

- Developing an approach to assess the impact of SF6 technology as compared to alternative technologies and gases

- Development of an industry-wide failure database

- Develop guidelines for live filling of SF6 insulated equipment

- Development of a comprehensive guidebook to enhance the utility knowledge base and provide a one-stop reference for GIS and GIL equipment

- Create application guides to aide utility engineers and field personnel with SF6diagnostic technologies

- Identify and evaluate available technologies for GIS and GIL diagnostics and evaluate emerging diagnostic technologies

- Develop a total life-cycle, systems based approach to compare gas-insulated and air insulated substation investments.

P37.111 - Risk Based Substation Equipment Asset Management

The P37.111 project conducts research with the goal of providing continually improved risk-based decision-support methodologies for substation equipment asset managers. It envisions that the developments will lead to an integrated framework for asset risk assessment, mitigation, and performance improvement. Developments in risk-based fleet management are addressed through the following tasks:

- **Asset characterisation and performance information (also known as asset registries):** Data models for the following substation equipment will be developed and documented in a technical report: Transformers, Circuit Breakers, Relays, Arresters, CCVT, Substation Batteries and Ground Grid.

- **Industry wide equipment performance and failure database and analytics**: Under this task EPRI will deliver version 2.0 of web based Transmission & Substation Industry wide Database. Under this task EPRI will also deliver a technical report that documents analytical approach, key findings and case studies from the analysis of industry-wide transformer data.

- **Asset health algorithms and software:** New versions of software tools for circuit breakers and transformers were delivered in 2015. In 2016 the circuit breaker and transformer software packages will be updated with new algorithms and features. In addition a methodology for assessing disconnect switches, CCVT's and relays will also be delivered.

- **Triggers and alarms for maintenance actions**: In 2016 a technical report documenting triggers and alarms to help with maintenance actions for circuit breakers, transformers, station insulators and CCVT's will be developed and delivered. The triggers and alarms documented in the report use data from online sensors/monitors and can be implemented in an enterprise wide asset health system such as NG's Strategic Asset Management (SAM).

- **Substation equipment asset management and maintenance practices:** A technical report using web based survey will be

developed and delivered. Over 25 US and International members will be surveyed. The focus is on learning about present asset management and maintenance approaches and sharing lessons learned with the industry. Topics include – transformers, circuit breakers, disconnect switches, SF6 leaks, infra-red inspections, ground grid and corrosion.

- **Evaluation of DGA Analytics:** A report evaluating the performance of EPRI developed analytics with other publicly available approaches will be delivered. Different approaches (including EPRI's analytics) are evaluated and their performance measured using blind test approach.
- **Asset management workshop**: Annual conference to assist technology transfer.

Objective(s)

The objectives for 2016 include the continuation of National Grid's membership with EPRI P37 and the delivery of value, a selection of reports and guidance documents associated with the three work-streams.

P37.101 - Transformer Life Management objectives for 2016

1. Transformer On-line Monitoring Technologies
This project will continue to develop and execute test protocols to scientifically understand online monitoring systems. The test protocols will cover a three tier test approach. The research will allow further understanding of the technologies and their capabilities and help maximise the diagnostic value.

2. Novel Sensor Development
The objective of this work package is to start to deploy into substations the specialised sensor hardware that was developed in the laboratory to provide insights into transformer health that are not obtainable using traditional techniques—or provide a step increase in robustness or a step decrease in overall costs.

3. EPRI Power Transformer Guidebook
Development and maintenance of a comprehensive transformer reference book that includes all aspects of transformer operation, maintenance, procurement and life-cycle management, is complete and will be kept up-dated at regular intervals. It is written from the perspective of a utility engineer and addresses all phases of a transformer.

4. Improved accuracy of transformer remaining life estimation
There is a possibility that using the estimation method proposed may produce useable results without the detailed knowledge of the transformer oil history. The resulting guidelines may help request a set of specific analyses from laboratories and interpret the results with improved accuracy.

5. Transformer life extension
By the end of the demonstration, the objective of this work is to have a robust, continuous online filtration of moisture using membrane technologies and which requires minimal maintenance. If successful it will offer the potential to significantly extended life of the transformer. The research has completed a year of field tests with the first prototype. Improvements have been incorporated into a new V2 prototype.

6. Transformer forensics – linking diagnostics and maintenance with true internal condition
The objective is to develop a forensics library providing members with new insights into likely end-of-life scenarios for the increasing population of aging transformers. Equally importantly, the library aims to help assess how effective the diagnostic tools are in predicting the true internal condition of the transformer. In 2016 the objective will be to extend the library further with specific focus on transformers that were heavily monitored prior to retirement.

7. Transformer ratings
Continue the development of a Transmission Rating Workstation (TWR) tool to provide and industry-standards-based methodology for rating transformers.

P37. 108 - SF6 Management and Gas Insulated Substations objectives for 2016

The intent of this project is to help users of SF6 circuit breakers and gas insulated substations through research and development of methods and processes to reduce maintenance costs, minimise degradation of equipment, minimise the risk of equipment failure, and minimise the potential for SF6 emissions by applying new technologies and improving GIS and GIL equipment life-cycle management.

GIS and GIL equipment research and development focuses on developing methods, technologies, and support documentation to help utilities make prudent asset management decisions. These decisions are necessary to minimize GIS and GIL equipment life-cycle costs and maximise equipment performance within an acceptable risk level.

P37.111 - Risk Based Substation Equipment Asset Management objectives for 2016

This project conducts research with the goal of providing continually improved risk-based decision-support methodologies for substation equipment asset managers. It envisions that the developments will lead to an integrated framework for asset risk assessment, mitigation, and performance improvement. Developments in risk-based fleet management are addressed through the following tasks:

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- **Triggers and alarms for maintenance actions:** In 2016 a technical report documenting triggers and alarms to help with maintenance actions for circuit breakers, transformers, station insulators and CCVT's will be developed and delivered. The triggers and alarms documented in the report use data from online sensors/monitors and can be implemented in an enterprise wide asset health system such as NG's Strategic Asset Management (SAM).

- **Evaluation of DGA Analytics**: A report evaluating the performance of EPRI developed analytics with other publicly available approaches will be delivered. Different approaches (including EPRI's analytics) are evaluated and their performance measured using blind test approach.

- **Asset management guidelines:** A technical report providing guidelines to utility asset managers on how to implement asset management program using enablers provided by EPRI research.

- **Asset management workshop:** Annual conference to assist technology transfer.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

Continuing to expand National Grid's knowledge and deliver value to our stakeholders, participation in P37 during 2016 means the provision of a range of specific outputs across the three project work-streams.

P37.101 – The anticipated outputs for Transformer Life Management in 2016 include:

1. **DGA Research on new markers:** Research to discover new markers in transformer oil to better assess transformer risk of failure. Technical report documenting research methodology, underlying approach, 2016 tests and results.
2. **Novel sensors development:** Technical Report documenting progress on research on optical technologies to provide non-contact diagnosis of energised bushings.
3. **Copper Book (also known as Power Transformer Guidebook):** updated comprehensive guidebook on transformer life management.
4. **Improved remaining life assessment**: methodology on how to better assess transformer remaining life.
5. **Robotics for transformer internal inspection**: Detailed internal transformer inspection without lowering oil.
6. **Forensics Library**: A shared database on how diagnostic predictions aligned with actual condition
7. **TRW (Transmission Ratings Workstation):** An updated software tool for rating all components on a utility circuit.

P37. 108 - The anticipated outputs for SF6 Management and Gas Insulated Substations in 2016 include:

- Live filling technical report outlining progress made to date on small and full scale laboratory testing.

- Updated presentation to EPRI members at the Transmission Task Force meeting in Albany New York in July 2016 and the European task force meeting in December 2016.

P37.111 - The anticipated outputs for Risk Based Substation Equipment Asset Management in 2016 include:

- Power Transformer Expert System version 3.0

- Circuit Breaker Fleet Management Software version 3.0

- Initial release of the Condition Monitoring and Implementation Database (Software)

- Industry wide Transmission and Performance Database, web based software version 2.0

- Vintage Guide Development, bushings technical report

- CCVT Asset Management Analytics, methodology development technical report

- Disconnect Switch Asset Management Analytics, methodology development technical report

- Protection Asset Management Analytics Development Methodology, 2016 status update report

- Substation Equipment Asset Registries: Transformers, Circuit Breakers, Relays, CCVT's, Arresters, Batteries and Ground Grid technical report
- Evaluation of DGA Analytics technical report
- Substation Equipment Asset Management and Maintenance Practices technical report
- Transformer Industrywide Database, key findings and case studies technical report
- Triggers and Alarms for Specific Maintenance Actions technical report

Project Partners and External Funding

n/a

Potential for New Learning

n/a

Scale of Project

The work-streams associated with P37 are predominantly laboratory or desk based projects, with a minimal amount of site trials, if and when required. Because of this approach, there is no scope to reduce the scale of the projects any further.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL6 Large Scale

Geographical Area

The research undertaken in the EPRI Substations programme is predominantly carried out in the US, with some work in the UK, although the programme also reviews the latest research from across the world. Additional testing facilities in Canada may be used, where appropriate.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

The total indicative NIA expenditure for 2016 is £300,000.

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)

The three P37 project work-streams that form this NIA project - transformers (P37.101), SF6 (P37.108), and asset management (P37.111) - offer different financial savings, based on the associated outcomes and potential benefits gained, year on year.

Each EPRI programme that National Grid joins has been through several 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 based on which programme will provide potential value from a GB perspective as part of an annual review of programmes to participate in.

Following previous participation in P37, it is expected that enduring involvement in P37 will facilitate the continued generation of valuable learning that will improve and maintain the reliability of the GB Transmission 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

Assets containing 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 as well as 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)

This project sits within the Managing Assets and Corporate Responsibility value areas of the electricity transmission owner innovation strategy.

☑ 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