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

Sep 2015

### Project Reference Number

NIA_NGET0172

## Project Registration

### Project Title

EPRI Research Collaboration on Substations

### Project Reference Number

NIA_NGET0172

### Project Licensee(s)

National Grid Electricity Transmission

### Project Start

September 2015

### Project Duration

0 years and 11 months

### Nominated Project Contact(s)

Iliana Portugues

### Project Budget

£1,662,515.00

### Summary


**Transformer Life Management**

The transformer programme is looking at seven themes to improve the knowledge and methodology for managing these assets. These will be delivered through

- Collating worldwide knowledge and experience.
- Researching and developing new technologies with academic organisations and research institutes.
- 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.

**SF6 Management and Gas Insulated Substations**

The SF6 research project is looking at several themes delivered through six different routes:

- Research into SF6 leak sealing and detection technologies
- Scaled laboratory testing in the EPRI Charlotte Laboratory and other external laboratories
- Full-scale laboratory testing
- Computer modelling of high risk scenarios
- High voltage testing under worst-case simulated conditions
- Field demonstration and testing in substations

**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 the following tasks:

- Asset health algorithms and software
- Asset health aggregation
- Substation Equipment Maintenance Basis
- Triggers/alarms for maintenance actions
- Substation equipment asset management and maintenance practices
- Asset management guidelines
- Asset management workshop

## Nominated Contact Email Address(es)

box.NG.ETInnovation@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 2015, a benchmarking exercise by National Grid has determined the largest leverage within Substations for the UK consumer is achieved through involvement in the transformers and SF6 programmes as well as the asset management work.

## Method(s)

Transformer Life Management

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## Scope

**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*

   A total of five different technology approaches to on-line gas analysis will be researched in small scale tests in a controlled environment using the research transformer, with the capability to simulate specific 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.

3. *EPRI Power Transformer Guidebook*

   This project will develop improved knowledge in the area of technological advances. In 2015 the Guidebook will expand the material on substation diagnostics (Chapter 9).

4. *Improved accuracy of transformer remaining life estimation*

   This work package will 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. In 2015 the work package will perform further develop on the drying technique and also demonstrate the prototype 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 2014 there were 16 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).

**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 SF6 diagnostic 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

**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 the following tasks:

- **Asset health algorithms and software**: New versions of software tools for circuit breakers and transformers were delivered in 2014. In 2015 the circuit breaker and transformer software packages will be updated with new algorithms and features. In addition a methodology for assessing disconnect switches will also be delivered.

- **Asset health aggregation:** A technical report describing methodology to assess the health of substation bay (transformers, adjacent switch and breakers) will be delivered in 2015.

- **Substation Equipment Maintenance Basis:** A technical report documenting the development of scientific basis for substation assets will be delivered in 2015. The work in 2015 focuses on transformers, circuit breakers and disconnect switches.

- **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.

- **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.

## Objective(s)

**Transformer Life Management**

1. *Transformer On-line Monitoring Technologies*

This project will develop 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 develop a specialized sensor hardware 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 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.

*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 2015 the objective will be to extend the library further with specific focus on transformers that were heavily monitored prior to retirement.

*7. Transformer ratings*

Development of a Transmission Rating Workstation (TWR) tool to provide and industry-standards-based methodology for rating transformers.

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**SF6 Management and Gas Insulated Substations**

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, minimize degradation of equipment, minimize the risk of equipment failure, and minimize the potential for SF6 emissions by applying new technologies and improving GIS and GIL equipment life-cycle management. GIS and GIL equipment R&D 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 maximize equipment performance within an acceptable risk level.

The 2014 objectives that were realized were:

*Technical Report - SF6 Capture Technology Status*

The role of SF6 capture is to provide a temporary solution for leaking SF6 for components that cannot immediately be taken out of service. The SF6 capture solution captures the leaking SF6 until the leaking component can be taken out of service and repaired or replaced. The benefits of this approach include:

- Reduced SF6 emissions during the interim period.
- Ability to avoid an unplanned substation outage to repair equipment that is leaking SF6,

  enabling this equipment to be serviced during planned outages.

The objective of this technical report is to:

- To update utilities and other stakeholders on the latest demonstration of SF6 capture methods.
- To identify needed next steps to prove this concept.

*Technical Report - Alternatives to SF6 Technology in Power Delivery, Status of Research*

The purpose of this Technical Update is to present utility industry professionals with new research findings, information on new projects, and developments in ongoing projects that focus on identifying, designing, developing, testing, and implementing potential alternatives to SF6 circuit breakers in the electric power grid. Covered are potential SF6 alternatives for both transmission and distribution voltages. The report is intended to inform and educate utility industry professionals whose work involves applications of SF6 technology.

*Technical Report - Gas-Insulated Substations and Lines Guidebook*

Utility asset managers and GIS/GIL equipment users need to be able to make informed, optimal decisions regarding the investment in and maintenance, repair, and replacement of GIS and GIL components.

The ideal future state includes risk-based asset management metrics and algorithms to understand the expected performance of aging GIS and GIL components, assess performance gaps, and support informed decision making regarding maintenance, repair, and replacement.

The objectives of this Technical Update

- To document failure statistics and trends
- To identify degradation mechanisms and links to failure
- To outline a research plan for GIS/GIL research

The 2015 objectives are:

*SF6 (Sulfur Hexafluoride) Computer-Based Training Module 4.1*

The development and documentation of effective methodologies for accurately capturing, storing and accessing SF6 data for EPA and other regulatory reporting throughout the life of gas insulated equipment is critical to user operations. Research will revise the SF6 Computer-Based Training Module(s) with respect to new or revised regulations and new or updated gas handling technologies. Research will provide update of the software on new concepts for fast detection and temporary leak sealing solutions.

*SF6 Live Filling Equipment Specification Guideline*

Live filling of SF6 equipment remains an emerging practice with uncertainty on its effectiveness. The objective of this report is to

develop guidelines for the optimal device for safely filling SF6 apparatus while the apparatus is energized.

*Gas Insulated Substations (GIS) and Lines (GIL) Guidebook*

A comprehensive text that covers this subject from the utility perspective is being developed. Chapters will be developed to include documentation of the GIS/GIL design and procurement processes from budgetary proposal to final approval of design. Chapters will be developed to identify of all possible degradation mechanisms and link them to potential failure modes to support a fleet management framework for GIS and GIL assets.

## Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

## Success Criteria

Specific outputs for 2015, Transformer Life Management include:

- Report reviewing five different detection technologies relating to both DGA and Acoustic Emissions.
- A prototype of a specialised sensor hardware system that provides insights into transformer health not obtainable through traditional techniques.
- EPRI Copper Book – An updated and extended transformer guidebook – including updated knowledge on condition monitoring.
- Report detailing the results from online field tests and analysing them to provide improved insights into end-of-life transformer assessment.
- Report detailing the design and trials of novel membrane technologies for lifelong oil filtration.
- Software tool for fast and accurate ratings of transformers and the complete circuits the transformers supply.

Specific outputs for 2015, SF6 Management and Gas Insulated Substations include:

- Updated SF6 (Sulfur Hexafluoride) Computer-Based Training Software
- Making operational the SF6 and GIS Laboratory in Charlotte for laboratory experiments and substation trials of SF6 leak detection techniques and sealing solutions as well as SF6 capture trials and proof of concept.
- Technical report describing guidelines for the optimal device for safely filling SF6 apparatus while the apparatus is energized.
- Gas Insulated Substations (GIS) and Lines (GIL) Guidebook Technical Report; chapters will be developed to include documentation of the GIS/GIL design and procurement processes from budgetary proposal to final approval of design. Chapters will be developed to identify of all possible degradation mechanisms and link them to potential failure modes to support a fleet management framework for GIS and GIL assets as well as reviewing diagnostic techniques for failure prevention.

**Risk Based Substation Equipment Asset**

- New versions of transformer and circuit breaker health assessment software
- Report cataloguing assessment of asset management and maintenance practices
- Report detailing disconnect switch health assessment approach
- Report detailing substation equipment bay assessment approach
- Technology transfer session with NG tech staff

## Project Partners and External Funding

Each project facilitated by EPRI is funded through collaborators, including National Grid, that contribute to the development of the project portfolio and then express specific interest in being involved in a project once the portfolio is decided.

Total contributions from other EPRI members for these projects is of £1,442,515.

## Potential for New Learning

**Transformer Life Management:** Transformers are a key component of substations. This programme has the potential to provide new learning through:

- Improved understanding on how to maximize value from emerging condition-monitoring techniques
- Novel sensors to measure parameters presently not available for on-line measurement.
- Improved estimates of the remaining life in transformers, providing improved insights into likely end-of-life scenarios for the increasing population of aging transformers
- Extended transformer life through application of novel filtration materials and techniques
- Improved decision making on replacement, diagnosis, or refurbishment of transformers through the growing forensics database
- Novel methodologies for rating transformers and other equipment on the same circuit.

**SF6 Management and Gas Insulated Substations:** Gas-Insulated Substations (GIS) and Lines (GIL) offer many benefits including compact size, modularity, physical security and protection from pollution and harsh environments. This project will provide us with new learning in the areas of:

- Reducing cost and potential of SF6 emissions
- Developing improved handling and live filling techniques
- Improving diagnostic techniques for reduction of life cycle costs
- Improving failure prediction and prevention for improved reliability

**Risk Based Substation Equipment Asset Management:** The research will enhance asset management decision making processes and improve their results. The development provides tools and methodologies that can be used by substation equipment asset managers for improved decision support, including the following:

- Provides an analytical framework for asset management principles of substation equipment
- Reduces overall maintenance costs, forecasts operations and maintenance needs, minimizes unplanned expenses, and maximizes the benefit and value of planned work
- Improves reliability and availability via reduced reliance on time-based maintenance by using analytics based on asset health and risk and condition analysis to determine maintenance actions
- Enables more effective use of existing infrastructure and data, as well as efficient use of maintenance personnel to manage operational risk

Collectively, the developed suite of algorithms serves as the framework for Analytics for Substation Asset Management.

## 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

TRL5 Pilot Scale

## Technology Readiness at End

TRL7 Inactive Commissioning

## 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 NIA expenditure for 2015 is £263,000

# 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

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)

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.

By participating in collaborative projects through EPRI National Grid can ensure that unnecessary duplication with other projects under NIA is avoided.

### 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