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NIA Project Registration and PEA Document

Date of Submission

Dec 2021

Project Reference Number

NIA2_NGET0012

Project Registration

Project Title

EPRI Research Collaboration on Underground Transmission (P36) 2021-2025

Project Reference Number

NIA2_NGET0012

Project Licensee(s)

National Grid Electricity Transmission

Project Start

December 2021

Project Duration

4 years and 1 month

Nominated Project Contact(s)

Siyu Gao (Box.NG.ETInnovation@nationalgrid.com)

Project Budget

£2,063,000.00

Summary

Underground transmission assets are critical to any electricity network. Maintenance and life extension are the core work of cable asset managers as replacements of these assets would usually incur substantial capital investments. Cable assets are complex physically and chemically and thus significant trailing and testing in different environment are crucial to understand their behaviour, performance and failure modes. Statistically diverse data sets are also important for improving their management. In this project, NGET will collaborate with EPRI to carry out fundamental research and various experiments regarding cable assets to understand their behaviour, performance and failure modes under different conditions and environment. NGET will use the learning gained to improve its own cable asset management practices to deliver benefits for consumers.

Preceding Projects

NIA_NGTO28 - EPRI Research Collaboration on Underground Transmission (P36+ P34 part) 2018 - 2021

Third Party Collaborators

Electric Power Research Institute

Nominated Contact Email Address(es)

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Problem Being Solved

Underground cables and their related assets are critical and high value to any electricity network. Maintenance and life extension are the core work of cable asset managers as replacements of these assets would usually incur substantial capital investments. With the relatively small cable asset population owned by NGET and the high costs related with inspections and sampling, it has been difficult to implement some of cost saving deferment in cable asset replacements, e.g., 132kV CSEs replacements, since validated

interpretation of the forensic evidence was not achieved. With new cable technologies coming into service, e.g., 600kV MIPPL HVDC cables, 525kV XLPE HVDC cables, such problems could be worsened. NGET would be much benefited if it could: (1) have access to other cable users' condition data and their practices regarding cable maintenance and management; (2) have access to highly skilled and scarce cable expertise; (3) be kept up-to-date about the latest cable issues and development trend in areas of particularly rapid change, e.g., HVDC cable technologies.

Method(s)

NGET 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 whose solutions require statistically diverse data sets and/or significant trialling and testing in different environments, under various conditions and/or diverse ways.

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 NGET 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 comprises of 5 sub-projects. P36.001 will carry out outdoor experiments and investigations on a 132 kV CSE test rig. They include ageing tests, DGA analysis, borescope inspection experiments, acoustic emission monitoring, etc. This sub-project is expected to generate information regarding the ageing mechanisms and failure modes of HV CSEs.

P36.002 will conduct a series of laboratory experiments on XLPE cables, including thermal cycling and mechanical bending. This sub-project is expected to generate new and improved understanding regarding XLPE cable ageing and failure mechanisms.

P36.003 will conduct a series of laboratory experiments on laminar cables, including trialling and testing new technologies for online and off-line condition assessment and failure root cause analysis. It is expected that this sub-project will generate new learning and improved understanding regarding end of life management and asset life extension for laminar cable systems.

P36.006 will continue to investigate, collate and update the best practice and latest development regarding underground transmission. It is expected that this sub-project will be able to generate learning that could improve underground transmission system design and improve the execution of cable projects.

P36.008 will develop new software that could be used to calculate the rating and ampacity requirement for HVDC cable systems. It will also develop new inspection and monitoring techniques that could be used to improve HVDC maintenance and life extension.

Data Quality Statement (DQS):

- The project will be delivered under the NIA framework in line with OFGEM, ENA and NGET internal policy. Data produced as part of this project will be subject to quality assurance to ensure that the information produced with each deliverable is accurate to the best of our knowledge and sources of information are appropriately documented. All deliverables and project outputs will be stored on our internal sharepoint platform ensuring access control, backup and version management. Deliverables will be shared with other network licensees through following channels:
 - Executive summaries of EPRI reports through the EPRI website
 - Closedown reports on the Smarter Networks Portal.
 - Journals and paper publications
 - UK wide conference organised by NGET and EPRI annually

Measurement Quality Statement (MQS):

- The methodology used in this project will be subject to supplier's own quality assurance regime. Quality assurance processes and the source of data, measurement processes and equipment as well as data processing will be clearly documented and verifiable. The measurements, designs and economic assessments will also be clearly documented in the relevant deliverables and final project report and will be made available for review.

In line with the ENA's ENIP document, the risk rating is scored 7 = medium.

TRL Steps = 1 (2 TRL steps)

Cost = 3 (> £1m)

Suppliers = 1 (1 supplier)

Data Assumption = 2 (Assumptions known but will be defined within project)

Scope

The scope includes 5 sub-projects. They are the following:

- P36.001: Design, construction, ratings and operation of underground transmission systems
 - One of the main focuses is to study the failure modes and ageing mechanisms of cable seal ends (CSEs)
 - Other focuses include reliable performance of cable accessories, pipe-type to extruded cable conversion, transmission vault inspection using robotic techniques, performance and failure report for underground transmission cables and accessories, etc.
- P36.002: Extruded dielectric cable systems
 - One of the main focuses is the thermo-mechanical characteristics and performance of XLPE cables
 - Other focuses include advanced sensors and inspection techniques, ageing characteristics of extruded dielectric cable systems and components, asset vintage guide for extruded dielectric cables, terminations and joints, technology review of extruded dielectric EHV cable systems, etc.
- P36.003: Laminar dielectric cable systems
 - One of the main focuses is the life management for paper cables
 - Other focuses include inspection, assessment and mitigation of buried steel pipe corrosion, new technique development for online and off-line condition assessment, guidelines for insulating paper and fluid test, guidelines for dissolved gas analysis, vintage pipe-type cable performance and experience, failure root cause study, etc.
- P36.006: Principles and practices of underground transmission
 - Framework of the comparison of overhead and underground power transmission
 - EPRI guidebook for increased power flow
 - Underground transmission education workshops
 - EPRI reference book for underground transmission
- P36.008: HVDC cable systems
 - Advanced fault locationing for HVDC cables
 - EPRI HVDC transmission reference book
 - Underground transmission workstation – DC ampacity (software)
 - Guide on HVAC and HVDC array and export power cables for offshore wind farms

Objective(s)

The objective of this project is to address the challenges related to design, construction, installation, operation and maintenance of underground transmission systems. Cross-cutting research addresses issues such as design calculations, cable ratings, and inspection technologies. Research on CSEs aims to understand the failure mode and ageing mechanism of HV CSEs. Research specific to extruded dielectric cable systems aims to understand the thermo-mechanical behaviour and performance of XLPE cables and accessories so that to understand the related ageing characteristics. Research specific to laminar dielectric cable systems is concentrated on cable and system diagnostics, buried steel pipe corrosion, and failure root causes. The HVDC part of the project aims to provide easy to use software tools to evaluate and validate the continuous ratings of HVDC cables and also to understand the latest development in HVDC cable technologies. Continuous knowledge capture and sharing is also part of the objective.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

Financial distributional impact:

This project ensures that NGET and the UK energy industry are at the forefront of global developments in underground transmission system research, enabling the industry to make decisions that could reduce cable asset replacement and thus reduce capital expenditure and are supported by comprehensive research and experiments. With access to the latest research in underground transmission and statistically diverse data sets, NGET will be able to manage underground transmission systems more efficiently and effectively which could deliver savings. Furthermore, the leveraged funding mechanism in EPRI programs ensures that expensive research can be carried out at subsidised rates, thereby ensuring the best value for consumers' money. The project will not restrict benefits delivered to vulnerable consumers based on any vulnerability class.

Success Criteria

The project is deemed as successful if the objectives are achieved, specifically:

- Ageing tests and failure mode tests are carried out using the 132 kV CSE test rig. The results are collected and analysed and then are documented into the project reports and relevant deliverables.
- Thermo-mechanical bending tests are carried out on various XLPE cables. The results are collected and analysed and then are documented into the project reports and relevant deliverables.

- Sufficient knowledge gained on the management and maintenance of HVAC and HVDC array and export power cables for offshore wind farms.

Project Partners and External Funding

Each strand facilitated by an EPRI P36 program is funded through collaborators, including NGET, that contribute to the development of the project portfolio and then express interest in to be involved with a specific strand once the portfolio is decided. The total contribution to P36 from all the EPRI members over the next five years is expected to be in the region of £16.7m (based on 2021 rates).

Potential for New Learning

The potential new learnings from this project are the followings.

- Ageing mechanism and service life management of HV CSEs
- Thermo-mechanical characteristics and performance of XLPE cable systems
- Ageing characteristics and mechanisms of XLPE cables and laminar cables
- Advanced sensing, diagnostics and inspection techniques for XLPE cables and laminar cables
- Advanced online and offline condition assessment techniques for XLPE and laminar cable systems
- Improved understanding for the failure modes of HVAC and HVDC array and export power cables for offshore wind farms
- Improved understanding of the failure modes of CSEs, XLPE cables, laminar cables and HVDC cables
- Improved understanding of the performance of different insulation and conductor materials used in different cables
- Cost reduction in constructing and installing underground transmission cables
- Improved asset management and replacement strategies for cable assets

The learnings will be disseminated through the publication of project closedown reports. The executive summaries for EPRI reports are freely available from EPRI's website. The learnings will also be disseminated through the annual advisory and sector council meetings.

Scale of Project

The scale of the project includes the followings.

- Tests and experiments on a 132 kV CSE test rig outdoor
- Laboratory based analyses of samples from field-aged cables and accessories
- Thermo-mechanical bending cycling of XLPE cables in controlled indoor laboratory environment
- Controlled laboratory tests and validations for engineering design models and to understand failure mechanisms for end of life management
- Field demonstration of diagnostic methods
- Software development for various tools, including ampacity calculations, rating calculations, magnetic field calculations, etc.
- Various indoor and outdoor experiments related to underground transmission studies in general
- Writings for various reports, reference books and materials

Cable assets are complex physically and the chemical characteristics of cable components change with time as a result of ageing and other activities. Thus, they are extremely difficult to build computer models that can correctly and effectively represent cable assets, especially when it comes to ageing. Therefore, desktop study would not be sufficient. Laboratory based experiments, tests and analyses are the most reliable and effective way to study cable assets.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

The project will mainly be laboratory based. The work will be carried out at the supplier's premises, mainly in Lenox, USA.

Revenue Allowed for the RIIO Settlement

Not Applicable

Indicative Total NIA Project Expenditure

Total NIA expenditure: £1,856,700

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:

This project supports the energy transition through efficient investment of capital to ensure transmission reliability is maintained at a reasonable cost considering the more electrification of the society is expected in future

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

Not applicable

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)

Not applicable

Please provide a calculation of the expected benefits the Solution

The benefits of this project are based on two assumptions. The first one is that NGET will replace the 275 kV and 400 kV CSEs in the next 10 years. The amount would be the same as the 132 kV CSE's in T2. If this project is successful, 30% of the replacement can be deferred into the next 15 years. The second assumption is that NGET will be able to use the knowledge gained in this project to save half a day worth of constraint cost in the next 10 years. The NPV benefits over the next 15 years is about £1.78m.

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

This project focuses on cable assets at transmission level voltages and thus the learning may not be applicable to Network Licensees' systems that operate at lower voltages. In assessing the potential benefits of the project, the estimation is that there are 158 potential sites could be benefited from the deferment of CSE replacement. There are 6 HVDC interconnectors in the UK which could benefit from the constraint cost reduction.

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

The rollout of the method would be on existing CSEs and HVDC assets. The method should largely involve improved inspection, maintenance and asset management practices that would enable longer service life for CSEs and fewer outages for HVDC. The cost of the rollout is expected to be substantially lower than asset replacement as there is no involvement of purchasing expensive new HV assets.

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

Outcomes from this project will be disseminated through various channels such as:

- Executive summaries of EPRI reports through the EPRI website
- Closedown reports on the Smarter Networks Portal.
- Journals and paper publications
- UK wide conference organised by NGET and EPRI annually

Relevant Network Licensees will be informed about the most up-to-date learnings generated to review their own cable system management and maintenance strategies, feed into stakeholder engagement on upcoming works, etc.

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

Not applicable

Is the default IPR position being applied?

- Yes

Please demonstrate how the learning from the project can be successfully disseminated to Network Licensees and other interested parties.

The executive summaries of EPRI reports can be access freely through EPRI's website. Network licensees and other interested parties can thus obtain them for no cost. The closedown reports of the projects are also freely available on the Smarter Network Portal.

In addition, NGET and EPRI organise an annual conference in the UK to present and to disseminate results and outcomes from all the projects that GB Network Licensees subscribe to. The conference is open to all transmission and distribution network licensees, irrespective of their involvement in the projects. Information from each project is made available to all relevant parties to ensure an open environment for learning to be shared.

Please describe how many potential constraints or costs caused, or resulting from the imposed IPR arrangements.<

Due to the high proportion of third-party funding leveraged from sources other than the NIA, the alternative IPR arrangements for EPRI projects does not lead to consumers incurring excessive costs due to the relevant projects deviating from the default IPR arrangements. Other transmission and distribution network licensees have the option of obtaining access to the learning on commercial terms and, as described above, some leaning is available to interested parties.

Please justify why the proposed IPR arrangements provide value for money for customers.

EPRI is a membership organisation which uses funds from a number of sources to carry out RD&D of common interest to funders. The majority of the funding for its projects comes from third party organisations and NGET will have access to, and the ability to use, all IPR generated by the projects it has participated in (not just the learning and IPR NGET directly funds). This means that the learning NGET, network licensees, and other interested parties receive will be valuable relative to the cost of obtaining it. On balance, the IPR arrangement with EPRI provides appropriate value for money for customers.

This justification has been approved by Ofgem as per the 'Non Default Intellectual Property Rights (IPR) Arrangements for Electric Power Research Institute (EPRI) Projects' letter dated 8th February 2017.

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.

This project builds on the work that was carried out in T1 but does not duplicate them. There may be other projects in development looking at CSE ageing mechanisms and failure modes at lower voltage levels. The risk of duplication will be addressed through dissemination of progress with other licensees and being open to co-operate with licensees working in similar areas.

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

Not applicable

Additional Governance And Document Upload

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

EPRI P36 focuses on carrying out high-quality novel research in the field of underground transmission. They include innovative activities such as outdoor CSE ageing test, thermo cycling and mechanical bending on XLPE cables to characterise the ageing mechanism and failure modes of XLPE cables, identification of novel ageing markers for XLPE materials, novel condition assessment techniques for laminar cable systems, accelerated calculation methods for HVDC rating and ampacity, etc. All these activities are directed towards progressing novel fundamental research in the field which involves innovative elements that have not been explored before.

Relevant Foreground IPR

The foreground IPR will be the research outcomes regarding CSE ageing mechanisms and failure modes, thermo-mechanical performance of XLPE cables, ageing mechanisms and failure mode of XLPE cables, maintenance and management of laminar cables, methods for fault locationing for HVDC cables, management and maintenance for offshore export power cables, etc. These outcomes will be delivered in the form of new and/or updates to existing technical reports, reference materials, software packages, etc.

This project does not comply with the default IPR position, EPRI retains the ownership of the Foreground IPR. Only EPRI members can have full access to the information. Some learning can be shared through NGET's membership of EPRI. This IPR position is approved by OFGEM as per "Non Default Intellectual Property Rights (IPR) Arrangements for Electric Power Research Institute (EPRI) Projects" letter dated 8 Feb. 2017.

Data Access Details

Data for this project and all other projects funded under the Network Innovation Allowance (NIA), Network Innovation Competition (NIC) or the new Strategic Innovation Fund (SIF) can be found or requested in a number of ways:

- A request for information via the Smarter Networks Portal at <https://smarter.energynetworks.org>, to contact select a project and click 'Contact Lead Network'. National Grid already publishes much of the data arising from our innovation projects here so you may wish to check this website before making an application.
- Via our Innovation website at <https://www.nationalgrid.com/uk/electricity-transmission/innovation>
- Via our managed mailbox box.NG.ETInnovation@nationalgrid.com

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

This project involves longer term research at low TRL, which inherently has higher risk of failure. It also involves large amount of HV tests whose outcomes could be quite uncertain. Due to the low TRL and risk associated with this project, NIA funding is the correct mechanism rather BaU delivery.

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

There are technical risks associated with this project. Ageing mechanisms and failure modes for CSEs and other cable assets are known to be complex and they may not be fully identified in this project. Likewise, there is no guarantee that the fault locationing methods to be developed for offshore HVDC cables would definitely work. Considering the risks associated with this project, NIA is the most suitable route to support this project.

This project has been approved by a senior member of staff

Yes