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NIA Project Registration and PEA Document

Date of Submission

Apr 2025

Project Reference Number

NGED_NIA_079

Project Registration

Project Title

HV Pilot

Project Reference Number

NGED_NIA_079

Project Licensee(s)

National Grid Electricity Distribution

Project Start

April 2025

Project Duration

1 year and 5 months

Nominated Project Contact(s)

David Penfold

Project Budget

£901,477.00

Summary

Power flow analysis is vital to assess network capacity and the effects of future load growth. The reliability of this analysis depends on the precision of the underlying network model and data. A data gap exists in the network models regarding three-phase to single-phase connectivity, especially in rural low-voltage (LV) networks. These networks face unbalance risks as service cable and phase connectivity were not documented during installation. This project aims to address this by identifying solutions to ascertain the phase connection of single-phase transformers. The goal is to rebalance line connections, thereby releasing capacity through conductor reconfiguration, while improving the accuracy of network data for single-phase branches.

Third Party Collaborators

Loughborough University

CGI

Problem Being Solved

Electrical power distribution sees a pivotal shift from three-phase to single-phase connectivity, often underrepresented in network models. This transition greatly impacts network efficiency and reliability. Long-distance electricity transmission favours three-phase power for its efficiency and higher capacity over single-phase power. However, most residential and light commercial consumers use single-phase power. Higher loads connect to one phase of a three-phase cable, balancing customers across phases. Rural areas use single-phase feeder mains, needing only single-phase transformers. HV overhead spurs for single-phase transformers typically use a two-wire network on the same conductors of three-phase HV feeders.

Accurate modelling is crucial for predicting network changes, demand increases, and renewable integration, impacting performance. Inaccurate models risk inefficiencies and failures. Single-phase load variability challenges load balancing, causing voltage fluctuations and increased equipment wear. Managing unbalance in rural LV networks faces challenges due to insufficient three-phase to single-phase documentation, worsened by low-carbon technologies like heat pumps and EV chargers, increasing losses and voltage variations. Optimally balanced loads could reduce losses and enhance capacity for these technologies.

Addressing data gaps requires thorough data collection on single-phase connections. Site visits to establish phase connectivity are costly, especially for pole-mounted transformers. The SMITN project shows smart meter data can identify phase connectivity for single-phase customers. HV networks benefit from advanced grid management systems capturing real-time data for dynamic modelling. The HV Pilot project aims to determine HV phase connections of single-phase transformers, using technology and advanced data management, including digital sensors, monitoring systems, and images identifying transformer phase connections.

Method(s)

The HV Pilot project aims to find solutions to accurately determine the phasing of high-voltage feeders and associated single-phase transformers in rural areas. This will be achieved by managing data from various sources like digital sensors, monitoring systems, and images. The goal is to enhance transformer phase connection reliability and precision for accurate network modelling and to determine the distribution network's hosting capacity for new LCT connections.

The earlier SMITN project developed methods for determining LV phase connectivity, but gaps exist at the HV network level. Recent advancements in network visibility, such as monitoring equipment at distribution transformers and smart meters, facilitate real-time data collection. Imagery from satellites and aerial photography enhances infrastructure understanding, offering ways to address network unbalance and improve LV network efficiency and reliability.

The project has five work packages: data investigation, infrastructure development, phase identification using smart meter data, phase identification using imaging data and machine learning, and dissemination and trial specification. Each package includes deliverables like data assessment, infrastructure design, algorithm selection, and report creation. The final deliverable is a SIF Beta trial application with a cost-benefit analysis.

WP1 involves organizing workshops to evaluate network data, including phase indicators on schematic diagrams, LiDAR data, and helicopter images, to create a network model for area selection. WP2 identifies hardware, software, and interfaces for data collection, integrating it for analysis. WP3 tests algorithms for phase identification using smart meter data, evaluates data issues, and documents learning outcomes. WP4 develops machine vision systems for phase identification, assessing methodologies and performance, and addressing data issues. WP5 compiles a Combined Findings Report, identifying optimal phase identification approaches, establishes a business case, and submits the SIF Beta application.

Scope

The scope of the HV Pilot project involves investigating and applying algorithms that use various data sources for the following use cases: 1) Accurate determination of high-voltage (HV) feeder phasing and associated single-phase transformer phasing in rural areas. 2) Integration and management of data from digital sensors, monitoring systems, images, and existing databases to enhance the reliability and precision of transformer phase connection information. 3) Utilization of smart meter data and machine vision for phase identification, ensuring the accuracy and effectiveness of these methods. 4) Development of infrastructure to support data collection and processing, enabling efficient analysis and interpretation.
If the project is successful, it will lead to improvements in data quality and availability, which will then allow for:

1. More accurate network planning by modelling unbalanced three-phase networks.
2. Reduced energy losses through better phase selection for new connections.
3. Enhanced load balancing, leading to fewer voltage complaints and reduced fuse operations from unbalanced phases.
4. Improved capacity for low-carbon technologies (LCTs) such as heat pumps, electric vehicle chargers, and photovoltaic systems.

5. Better targeting of network monitoring and reduced costs associated with manual surveys.
6. Identification and correction of data errors ahead of need.
7. Improved use of network data by third parties, contributing to a more efficient and reliable power distribution network.

The financial benefits from these improved outcomes are estimated to be approximately £2.5 to £2.8 million per annum within NGED’s licence areas, made up of:

- Savings from reduced voltage complaints and improved network balancing.
- Reduced network losses and customer bills.
- Savings from reduced manual survey costs for phase confirmation.
- Enhanced network planning and reduced costs associated with inaccurate fault location identification.

Objective(s)

1. Explore solutions for accurately determining the phasing of high-voltage feeders and associated single-phase transformers in rural areas. Investigate viable methods for accurately determining the phasing of high-voltage feeders and single-phase transformers in rural areas.
2. Integrate and manage data from various sources, including digital sensors, monitoring systems, images, and existing databases, to enhance the reliability and precision of transformer phase connection information.

3. Develop algorithms using smart meter data to identify the connection between low-voltage (LV) and high-voltage (HV) systems.
4. Identify a methodology to address high-voltage connectivity gaps, particularly for single-phase transformers, to maintain an efficient and balanced network.
5. Leverage recent technological advancements in network visibility, such as monitoring equipment at distribution transformers, smart meter data, and imagery from satellites and aerial photography, to address network unbalance issues.
6. Apply the algorithms developed for the test network to real-world scenarios.
7. Assess the performance of the algorithms and identify factors that affect their accuracy.
8. Capture the learning from the project and disseminate it to interested parties.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

N/A

Success Criteria

The project will be deemed a success if the following criteria are achieved:

- Successfully assessed and evaluated network data to identify the project sample areas.
- Analysed helicopter images to determine their usability and relevance for applying machine learning techniques.
- Compiled comprehensive reports on network data assessments, visual data analysis, and the outcomes of area selection.
- Identified and integrated suitable hardware, software, and interfaces to facilitate efficient data collection, processing, and analysis.
- Thoroughly tested and evaluated algorithms, to ensure they met the specified use case requirements.
- Produced detailed reports on selected algorithms, the development and optimisation of methods, and the learning outcomes from applying these algorithms.
- Developed a robust machine vision system for phase identification, complete with thorough methodologies, techniques, and performance analyses.
- Clearly summarised project findings and construction of a compelling business case and successfully developed a beta application.

Project Partners and External Funding

National Grid:
National Grid Electricity Distribution have a proven track record of delivering successful innovation projects that influence strategy and change DNO policy. We are always looking for ways to develop our innovation strategy to ensure we prioritise the most critical areas, aiming to be capability driven. The Innovation Team have robust project management governance and business engagement, to ensure successful delivery of projects like this.

National Grid will:

- Coordinate the project and ensure delivery is to the objectives specified in this report
- Provide relevant data and information regarding current practices
- Complete project closedown and dissemination activities
- Project sponsors are Gav Berry and Jordan Demuth-Pike from DSO Modelling and Analysis
- National Grid are providing a financial contribution of £76,410.

Loughborough University

- Leveraging its expertise gained from the Losses Investigation project and SMITN NIA projects, the team will provide guidance on
- Sample area selection to ensure the viability of the phase identification work and so that the results consider a network topology where phase unbalance is likely to be a concern
- Advise on the algorithms to be tested and strategies for enhancing the test network.
- Review the outputs of the algorithms with CGI to
- Extract learning, dissemination, and project closure activities.

CGI

- Utilising its expertise gained from working on our INM and SMITN NIA projects, the team will
- Establish the data handling and processing infrastructure, configure modelling for the test network, and
- Implement the selected phase identification algorithms.
- Deliver the machine learning component and conduct performance evaluations.
- Analyse the results, disseminating the learning, and ensuring the project’s successful closure.
- CGi are providing a financial contribution of £100,000 the project in the form of a free licence.

Smart Grid Consultancy (SGC)

Are a well-established organisation with over a decade of experience in successful delivery of Ofgem innovation projects on-time and under-budget. Their past record not only includes some strategically important outcomes including the creation of Flexible Power, but they have also championed the ongoing evolution of learning into BaU adoption. The knowledge and experience they bring to the project is expected to significantly reduce the risk of delivering the overall project objectives. SGC will provide project management and a range of subject matter expertise.

SGC are providing a financial contribution of £37,380 the project.

Potential for New Learning

The knowledge dissemination activity will cover the learning from the practical implementation of the algorithms to identify the HV phase connections of single-phase transformers, particularly in rural areas. This will outline how well the algorithms worked and what factors affected their success rate, such as the quality and availability of smart meter data and other data sources.
The learning from the integration and management of data from various sources, including digital sensors, monitoring systems, and imagery, will identify whether the additional complexity of combining these data sources results in improved accuracy compared to simpler methods. It will also detail the accuracy of the phase connection information and how it was validated using different data sources.

The learning will also include insights from the development of machine vision systems for phase identification, how these systems were validated to ensure they were suitable for use, and any practical issues encountered during the implementation.

- Learning will be disseminated during the project externally via:
- One or two HV Pilot Webinars
- LCNI (Low Carbon Networks & Innovation) Conference
- Innovation Showcase

These dissemination activities will ensure that the knowledge gained from the project is shared with other Distribution Network Operators (DNOs) and relevant stakeholders, promoting the adoption of best practices and further innovation in the industry.

Scale of Project

The HV Pilot project will be desktop-based and will utilize a sample area of rural networks with HV feeders that primarily use overhead lines. The region's selection depends on the accessibility of smart meter data and helicopter survey data. If the data is available, the project plans to apply its methods to the overhead HV feeders of approximately five primary substations.
The selection of the sample area will aim to include a diverse range of network configurations to ensure comprehensive testing and validation. This includes:

- Rural Overhead Networks: Areas with long line lengths and numerous pole-mounted transformers, making them ideal candidates for the project.
- Regions with Varied Data Availability: Areas where smart meter data, helicopter survey data, and other relevant data sources are accessible to support the project's objectives.

The project will also consider regions with both low and high existing concentrations of low-carbon technologies (LCTs) to evaluate the impact of these technologies on network performance and phase connectivity. While the core test network will focus on a smaller number of substations, the project aims to extend its functionality to include up to 100 distribution substations, depending on the availability of monitoring data.
By selecting a diverse and representative sample area, the HV Pilot project aims to ensure that its findings and methodologies are applicable across a wide range of network configurations and conditions, ultimately contributing to improved network management and planning.

Technology Readiness at Start

TRL4 Bench Scale Research

Technology Readiness at End

TRL7 Inactive Commissioning

Geographical Area

The project will be desktop-based and will utilize a sample area of rural networks. The selection of the sample area will depend on the accessibility of smart meter data and helicopter survey data. If the data is available, the project plans to apply its methods to the overhead HV feeders of approximately five primary substations.

Funding Licensee area for this project is within the National Grid Electricity Distribution (NGED) regions, specifically targeting rural areas in Devon or South Wales. These areas have been chosen due to their suitability for the project's objectives and the availability of relevant data sources.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

Total Project Cost - £901,477
Agreed Partner Contributions (SGC) - £37,380
Agreed Partner Contributions (CGi) - £100,000
Funding from ED2 - £0
Sub Total -£764,097
NGED DNO Contribution - £76,410
Funding from NIA - £687,687

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:

The HV Pilot project aims to facilitate the energy system transition by accurately determining HV phase connections, improving load balancing, and enhancing network capacity. By leveraging advanced technologies like smart meters and machine vision systems, the project will optimize the integration of low-carbon technologies (LCTs) and reduce energy losses. It will also generate valuable insights and methodologies for other Distribution Network Operators (DNOs), promoting best practices and further innovation. Overall, the project will enhance data quality and availability, supporting more efficient network planning and management, and contributing to a sustainable, resilient energy system.

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)

We expect the financial benefits to result from a reduction in voltage issues and related complaints costs, reduced losses, and reduced manual network surveying costs. These total to an estimated £2.5 – £2.8 million per annum

Saving Area - Amount Per Annum
Reducing Customer Voltage Complaints - £315k - £683k
Reducing Network Losses and Customer Bills - £205k
Reduced phase confirmation costs compared to manual survey - £2M
TOTAL - £2.5M - £2.8M

Please provide a calculation of the expected benefits the Solution

Not applicable as this project is a research project that is looking to develop a solution for identifying the phase connections of single-phase transformers, enabling the future re-balancing of line connections to free up capacity and enhance the precision of network data.

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

The output of this project will be relevant for all GB electricity network operators and can be implemented with no additional work.

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

As the project is a research piece relevant to all GB electricity network operators, no costs apply to rolling the project out.

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

The learning from the HV Pilot project can help other Distribution Network Operators (DNOs) improve phase connectivity data, enhance network modelling, and support low-carbon technologies (LCTs). By adopting advanced technologies and methodologies, DNOs can reduce operational costs and improve network management. The project's insights will promote innovation and best practices, contributing to the overall efficiency and sustainability of the energy system.

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

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.

N/A

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

N/A

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

N/A

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.

The HV Pilot project ensures no unnecessary duplication by building on the existing SMITN project, which developed smart meter phase identification algorithms. This project extends those algorithms to high-voltage (HV) networks, focusing on rural areas where phase connectivity data is lacking. It leverages unique methodologies, such as machine learning applied to helicopter survey imaging data, which have not been previously explored for transformer phase connections. Additionally, the project collaborates with specialized partners, ensuring that efforts are complementary and not redundant with other initiatives.

The methodology for this project has also been reviewed against other projects registered on the Smarter Networks Portal and circulated with other DNOs and TNOs ahead of registration to ensure no unnecessary duplications will occur.

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

The HV Pilot project is innovative because it leverages advanced technologies and methodologies to address the challenge of accurately determining the phase connections of high-voltage (HV) transformers, especially in rural areas. This project builds on the smart meter phase identification algorithms developed in the SMITN project, aiming to extend their application to HV networks. It explores the use of correlation techniques to identify transformer phase connections by analysing voltage variations from primary substations.

Additionally, the project employs machine learning to analyse helicopter survey imaging data, a novel approach that has not been previously applied to transformer phase connections. This method involves detecting insulator fittings and integrating network configuration data to accurately determine HV feeder conductor connections.

By combining smart meter data, machine learning, and advanced data management techniques, the HV Pilot project aims to improve the accuracy and reliability of network models. This innovation is crucial for optimizing load balancing, reducing energy losses, and enhancing the hosting capacity for low-carbon technologies (LCTs) such as electric vehicles and heat pumps. The project's success could lead to significant improvements in network efficiency and reliability, benefiting both the distribution network operators and their customers.

Relevant Foreground IPR

Relevant Foreground IPR

1. **Smart Meter Data Processing Algorithms:**
   - Algorithms developed for phase identification using smart meter data.
2. **Machine Vision Systems for Phase Identification:**
   - Machine vision methodologies and techniques for identifying transformer phase connections using imaging data.
3. **Data Integration and Management Techniques:**
   - Techniques for integrating and managing data from digital sensors, monitoring systems, and imagery to enhance the reliability and precision of transformer phase connection information.
4. **Combined Findings and Learnings Report:**
   - Comprehensive report detailing the combined phase identification approach, scenarios where each method performs best, and the overall learning outcomes from the project.
5. **SIF Beta Trial Application:**
   - Application for a SIF Beta trial, including a cost-benefit analysis and business case for further development and scaling of the project.

Background IPR

1. **Processing Algorithms to Replicate the Settlement Process:**
   - Held by CGI, used in the development of smart meter data processing algorithms.

The development of the machine learning process will generate new foreground IPR, which will be held by CGI but made available to third parties in accordance with NIA requirements. The algorithms applied to identify feeder phase are not expected to be protected by prohibitive IPR arrangements, such as requiring licensing for use, but rather being published in academic papers or developed by the HV Pilot team themselves.

Data Access Details

It is likely that the majority of underlying data which relates to individual MPANs cannot be shared. However the data behind charts in the final report and any suitably aggregated data will be made available on request. The data sharing policy is available here.

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

The Network Licensee is not funding the HV Pilot project as part of its business-as-usual activities because the project involves significant research, development, and demonstration of new technologies and methodologies that are not yet proven. These innovative approaches, such as the use of smart meter data and machine learning for phase identification, require extensive testing and validation before they can be integrated into standard operational practices.

Additionally, the project aims to address complex challenges in accurately determining HV phase connections, which involves substantial upfront investment in advanced data management and analysis infrastructure. The potential benefits, while promising, are still uncertain and need to be demonstrated through pilot studies before they can justify the costs associated with widespread implementation.

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

The HV Pilot project requires NIA support due to its complex resource needs, significant operational risks, and high upfront investment. NGED lacks the internal expertise for advanced technologies like smart meter data analysis and machine learning, necessitating specialist partners. The project aims to validate unproven methodologies, which involves substantial financial risk. NIA funding enables the exploration and refinement of these innovations, ensuring successful integration into business-as-usual activities and achieving strategic goals for network efficiency and reliability.

This project has been approved by a senior member of staff

☑ Yes