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

NIA Project Registration and PEA Document

Date of Submission

Mar 2024

Project Reference Number

NGED_NIA_074

Project Registration

Project Title

HV Pinpoint

Project Reference Number

NGED_NIA_074

Project Licensee(s)

National Grid Electricity Distribution

Project Start

March 2024

Project Duration

2 years and 7 months

Nominated Project Contact(s)

Scott Ball

Project Budget

£718,751.00

Summary

HV faults on the underground network account for a large proportion of unplanned outages, where customers may remain off-supply until the fault is found and repaired unless an alternative network arrangement is used to back feed. To help solve this problem, HV Pinpoint aims to develop a methodology for detection and precise location of pre-fault events in the HV underground network. This solution may be used in conjunction with the Pre-Fix NIA project method to provide a more precise defect location, or as an alternative pre-fault method. The intention of this is to reduce the reliance on test van methods, as well as providing a new solution to more easily retrofit sensor on to existing underground cables.

Preceding Projects

NIA_WPD_060 - Pre-Fix

Third Party Collaborators

Create Innovation Solutions

Loughborough University

Problem Being Solved

HV faults on the underground network account for a large proportion of unplanned outages, where customers may remain off-supply until the fault is found and repaired. Given the role of electricity in supporting the decarbonisation of transport, heat and industry, it is becoming increasingly important to find ways to proactively avoid these faults. Current fault finding methods are limited, as although a broadly correct defect location can be found through sectionalising, labour intensive test-van based methods are required for precise location of the fault before a repair can be planned.

NGED's Pre-Fix project started to address this problem by developing a pre-fault capability to proactively detect, locate and repair anomalies before they deteriorate into faults. The developed system also offers improvements to NGED's post-fault response by

reducing the time and resources required for locating faults. However, the Pre-Fix method is limited as although it can provide a pre-/post-fault location up to the correct circuit section, it cannot provide accuracy that is suitable to instruct excavation, and is currently untested at scale on NGED's network.

A precise defect location can be found using Partial Discharge (PD) mapping techniques, but we would like to find a more flexible method to pinpoint the anomalies. PD mapping faces certain limitations such as requiring on-site, offline testing using a specialised test van and not being applicable on multi-ended circuits. The suitability of this method to validate pecking events identified by Pre-Fix is also under question as it tests phase-earth defects whereas Pre-Fix has identified that most pre-fault activity is phase-phase. The results from PD mapping rely on experienced personnel to interpret them, are heavily weather dependent and cannot be used in a post-fault scenario. The operational capability of PD mapping is also a constraint due to the current limited number of test vans with the required equipment for PD mapping and availability of trained staff to carry out the testing.

Further problems related to Pre-Fix that this project aims to address is that the monitoring devices used within Pre-Fix rely on substation CTs, which are not installed in all substations, and alternative devices for detecting phase-to-phase activity require access to individual phases within switchgear end-boxes, which is invasive and time consuming.

This project will also address a problem from an asset management perspective. An analysis of the age profile of NGED's 11 kV cable population compared to the NGED DSO's Best View forecast for peak primary demand out to 2050 has revealed that a large spike in cables reaching their mean life expectancy coincides with a large increase in demand, related to the uptake of Low Carbon Technologies (LCTs) essential to the energy transition such as heat pumps and EVs. In order to make the best use of resources to address the spike in work required as the network ages, ultimately coming from customers' bills, whilst ensuring that the network can supply the demand required for net zero, being better at pinpointing the minimum amount of work to do on the old cables with enough capacity is essential to enable us to focus on reinforcing the old cables without enough capacity. The analysis shows this becoming increasingly important within three price control periods.

Method(s)

This project aims to develop a system and methodology for detection and precise location of pecking events in the HV underground network. This solution may be utilised by NGED in conjunction with the Pre-Fix method to provide a more precise location for detected anomalies, or as an alternative pre-fault method.

The work packages will focus on the research and development of several enabling technologies, consisting of existing low-TRL technologies and two completely novel street-level devices. These will be brought together into an integrated system that realises an end-to-end pre-fault management process which follows the steps of Detect, Locate, Validate and Pinpoint (described in the work packages below) to find a precise, validated defect location. The aim of this method is to reduce the amount of excavation required for repair (and therefore cost) through providing a pinpointed location and to improve confidence in this location through validation using a combination of independent technologies/methods.

This project will address certain barriers to scale of a HV pre-fault response capability by working towards the specific requirements below:

- Using sensing that doesn't require HV Line Circuit CTs
- Wraparound sensors capable of detecting both phase-phase and phase-earth pecking events which can be installed around cables leaving switchgear end-boxes
- Non-invasive live installation and operation
- Compatibility with a range of cable types, including three phase and triplex style cables
- Portable system not reliant on van-based techniques, which might be inappropriate given the intermittent nature of pecks, variance in predicted locations and resource limitations

Work Package 1: Detect

This work package will develop the capability to detect fractional cycle pecking events using wraparound 3-phase online HV sensors and Precision Event Timing Units (PETUs) at cable ends which upload data to a webserver. Outputs will include lab, training network and live network tests, upgrades to the existing PETUs and development of the webserver.

Work Package 2: Locate

This work package will develop the event location calculation using cable end PETUs and Time of Flight (ToF) methods. The location will be cross referenced with cable joint records, recent street works and Pre-Fix plotting of anomalies from iHost, before being plotted on a route mapping diagram. Outputs will include lab, training network and live network tests, development of the webserver and upgrading the mapping location system.

Work Package 3: Validate

This work package is focused on validating the mapped event position with its real-world position. A novel Pulse Injection Generator (PIG) will be developed which will be used to inject a sequence of pulses at the mapped location. This will be converted into a positional location which will be compared to the mapped location. The PIG will be moved and the process repeated until the distances converge, giving a validated real-world event position. Outputs from this work package will be an optimised design, device prototype and lab and live network tests.

Work Package 4: Pinpoint

This work package looks at finding a precise event location. A novel pinpoint board will be developed which can accurately detect the location of pecks within underground cables beneath it using electro-magnetic effects. The board will be placed over the validated location found in WP3. When the next event occurs, the mat will provide in-place fault location. This will be verified with the PETUs at all circuit ends and a repair job can be planned. Outputs from this work package will include a prototype pinpoint board, and lab and live network tests, initially targeting cables laid at a depth of 600mm.

Work Package 5: Integrated System

This work package is responsible for integrating the technologies developed in the other work packages into a working system. Outputs will include reviewing operational lessons, updating user and design requirements, optimising element designs, implementing and testing elements, lab testing the integrated prototype system, live network tests on known and unknown events, lessons and designs for live network trial systems and stage reports.

Work Package 6: Pre-Fault machine Learning

This work package aims to develop a trained machine learning model to analyse and categorise captured event data.

A training data set from a large volume of captured waveforms will be grouped in common classes of waveforms and those that repeat.

We will then input HV current events to create 3 phase HV waveforms and produce the equivalent LV waveforms through a DY11 transform to match class waveforms. This will then be repeated for LV - HV waveforms to match class waveforms. Together these are then used to train a machine learning system to recognised the various types of HV and LV events from recorded HV current waveforms and checked against previous known event examples.

Measurement Quality Statement

Measurement quality will form a key part of the analysis at the three testing locations set out for this project. We will analyse and validate the measurement quality of all sensors forming part of the system, and this will be used in deciding whether to proceed at the two stage gates set out in the project.

Data Quality Statement

Data will be captured at the lab, Sundridge and Coventry testing phases of this project. This will be processed and stored using the webserver that forms part of the HV Pinpoint system, with cyber security assurance being carried out prior to the commencement of this data capture.

Scope

The scope of this project is to pursue the research and development of a set of low TRL technologies, tested in lab, trial network and live network environments, which may be used as an integrated pre-fault management system within a novel methodology for pinpointing HV pre-fault defects on NGED's underground network. The method will use sensors capable of detecting phase-to-phase and phase-to-earth pecking events, which don't require substation Current Transformers (CTs) and can be installed and operated non-invasively without the need to break apart switchgear end-boxes. Novel street level devices will be developed for validating and pinpointing defects. The system will be applicable to three-ended circuits and not rely on test van based techniques, providing an alternative to PD mapping for precise cable defect location. This method may be used in conjunction with existing pre-fault systems, such as Pre-Fix, or as a standalone method.

This project generates direct benefits through providing a more practical and cost-effective alternative to PD mapping. Additionally, this new capability is intended to unlock the full benefits of a pre-fault capability in general, for example being used to provide a

pinpointed defect location from a broader location given by Pre-Fix methods. These benefits are captured through a reduction of fault management costs through operational savings and reduced IIS penalties, improved customer service through reduced CIs/CMLs and an improved basis for targeted asset replacement through improved visibility of the condition of the HV underground network. Customers will benefit from an increased reliability of supply, improved value for money and protected availability of supply to meet the increasing demand required for the uptake of LCTs.

Objective(s)

- Develop 3-phase online HV cable sensors capable of detecting phase-to-phase and phase-to-earth pecking events, which don't require CTs
- Develop a Pulse Injection Generator (PIG) which can be used to validate event location
- Develop sensor mat which can pinpoint events from street level
- Test the developed devices in lab, trial network and live network environments
- Combine the developed devices into an integrated system which can be used for end-to-end pre-fault management
- Develop a system which works on three ended circuits
- Develop system in a way which can be installed and operated non-invasively, without needing to break apart switchgear end-boxes, which can be used with a range of cable/switchgear types
- Develop a portable system not reliant on test van techniques
- Improve understanding of the cost of the devices and operational cost of the method, and how this could be scaled to rollout across NGED/other DNOs

Consumer Vulnerability Impact Assessment

There are no planned outages required for this project, so customers' supplies will not be interrupted at any time because of this project. The potential benefits of this solution will lead to a reduction in unplanned outages, increasing availability of supply for all customers including those with vulnerabilities. The overall cost savings this method could bring will also be passed on to all consumers, including those with vulnerabilities.

Success Criteria

This project will have been successful if the following outcomes are achieved:

- Demonstration of validated location of partial cycle and full cycle HV pecks using the prototype system elements developed in this project as an integrated fault management system
- Demonstration of repeated accuracy on a live system, including circuits with high background harmonic noise and switching noise
- Demonstration that sensors can detect pre-faults that are phase to phase, phase to earth, and all varieties of pre-fault that have activity on three phases
- Demonstration of reporting to a standalone data system with web interface
- Demonstration of non-invasive live installation and operation of equipment on NGED's network, which is widely applicable e.g. effective on a range of HV cable types and switchgear
- Production of optimised user and design requirements for the each of the prototypes developed as well as the whole system
- An improved understanding of the business case of using this method as a pre-fault capability within DNOs, either in conjunction with other pre-fault systems such as Pre-Fix or as a standalone method, and determining the next steps towards larger scale volume roll out of the systems

Project Partners and External Funding

Create Innovation Solutions (CIS) – responsible for developing the enabling technologies, some of which they have already been involved in developing to an initial stage

Potential for New Learning

This project will generate the following learnings that can be used by network licensees:

- Learnings from the development and design optimisation of the novel devices
- Insight into the feasibility of the proposed devices through completed lab, training network and live network tests
- Learnings from system integration, including how to interface constituent devices and software and how best to process and communicate data
- Operational learnings from installing the developed equipment on a variety of cable types/switchgear on a live network
- Learnings about the suitability of this method as an alternative to PD mapping for fine resolution defect finding

- Learnings about captured HV event waveform classification and filtration of LV/other network events
- Development of the business case for the methodology developed in this project to be rolled out at scale, including projected equipment and operational costs compared to the current BaU standards

Dissemination will occur through NGED's proven mechanisms, including but not limited to:

- Reports
- Innovation showcase events
- Regular website updates
- Presentation/publication at national and international conferences

Scale of Project

Development will be contained on a small scale, given that the technology is unverified on a live network. Testing will occur at various levels, beginning in a research lab at Loughborough University and progressing to the training and test network at the UKPN training centre in Sundridge (organised through Create Innovation Solution) and finally to NGED's live network. Testing on NGED's network will occur at selected sites in Coventry, which has some of the worst served customers of underground cables and historical HV fault activity.

This will initially be a standalone operation, without business system operation, to minimise risk on business standard practices, but will aim to present the case for larger scale roll-out, potentially through a follow-on project, and eventual BaU integration.

Technology Readiness at Start

TRL4 Bench Scale Research

Technology Readiness at End

TRL7 Inactive Commissioning

Geographical Area

Testing on NGED's network will occur in the East Midlands licence area, at selected sites in Coventry. Methods will be replicable across all license areas. Lab testing will occur at Loughborough University. Testing will also occur on UKPN's test network in Sundridge.

Revenue Allowed for the RIIO Settlement

All IPR generated during this project will be shared in line with the standard NIA IPR terms. This is expected to include: • Reporting on the design, development and testing of novel sensing devices. • Reporting on the design of the components and architecture of the Pre-fault detection system. • Trial outputs from the network trial planning in NGEDs region. • Test Plans • Sensor and whole system specification and design documents.

Indicative Total NIA Project Expenditure

NGED will contribute a value of £71,875 to this project, requiring NIA funding of £646,875. Reason for change: The HV Pinpoint PEA has been updated as the project end date has been extended due to ill health of a key member of the project partners personnel.

Project Eligibility Assessment Part 1

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations

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

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

The energy system transition will involve an increased dependence on electricity across all aspects of society. Maintaining a reliable and resilient network through avoiding faults or fixing them more quickly will help to ensure public confidence in the actions to achieve net zero and protect both people's lifestyles in their homes and the economy.

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

The project is about the identification of potential HV faults before they occur so that timely action can be taken to prevent a fault happening and customers being taken off-supply. Many categories of vulnerable customers are particularly exposed to risk by the failure of their electricity supply, for example those with critical medical equipment. Therefore, innovations that can prevent faults from occurring are beneficial to everyone but especially to vulnerable customers.

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

N/A

Please provide a calculation and/or description of the expected benefits of the solution

The benefits of using the method developed in this project as an alternative to PD mapping were estimated, considering the potential operational cost savings. To quantify this, an estimate for the amount of PD mapping required per year if Pre-Fix was rolled out across the business was derived. This was derived as both a lowball estimate and a highball estimate, to get an idea of the range of benefits this project could deliver.

For the lower estimate, we assumed that 376 circuit sections need to be PD mapped per year. This was estimated using data from Pre-Fix to suggest 6% have high enough pre-fault activity to instruct PD mapping. For the higher estimate, we assumed that 1000 circuit sections will need to be PD mapped per year. This is based on historic fault data from 2021 to 2023.

Using these bounds with an estimate for the equipment cost of £10k per depot in NGED's licence areas and an operational savings rate of 85%, the net benefit over one price control period ranges from £763k to £2.5M.

A more refined estimate of the equipment cost and operational savings compared to PD mapping will be determined throughout the course of this project.

The recipients of this benefit will be NGED through reduced OpEx costs. This may also ultimately benefit customers through reduced bills. There are further benefits associated with developing a pre-fault capability which were not quantified at this stage, including reduced CIs/CMLs which benefits customers through improved reliability of supply and NGED through reduced IIS penalties and OpEx

costs associated with post-fault response.

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

The method developed in this project is expected to be widely applicable across GB, as the technology developed is intended to be compatible with a wide variety of cables/switchgear.

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

Due to the low TRL of the technologies in this project, rollout across GB is not expected as an outcome from this project. As an initial estimate, we have considered an equipment cost of £10-50k per depot within NGED's licence areas. This could be scaled up to be applied to all depots across GB. At this stage we haven't got a view on the cost to roll out the method across the UK, but the project will confirm this.

Requirement 3 / 1

Involve Research, Development or Demonstration

Projects 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

Involve Research, Development or Demonstration - Please select all that apply

☑ 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

- Learnings from the development and design optimisation of the novel devices.

- Could be used by Network Licensees to specify devices which build on these learnings. It is intended that by sharing this information, existing supply chain will be able to take on board learnings and carry out development of devices suited to the Pinpoint system. This will increase market liquidity and reduce costs for all networks.

- Insight into the feasibility of the proposed devices through completed lab, training network and live network tests.

- Could be used by Network Licensees to understand how these devices may be applicable on their networks.

- Learnings from system integration, including how to interface constituent devices and software and how best to process and communicate data.

- Could be used by Network Licensees to understand how the developed system could work with the existing devices and communications protocols on their networks.

- Operational learnings from installing the developed equipment on a variety of cable types/switchgear on a live network.

- Could be used be used by Network Licensees to understand if the devices could be installed on their network, and to aid operational teams with installation if this solution is rolled out.

- Learnings about the suitability of this method as an alternative to PD mapping for fine resolution defect finding.

- Could be used to justify using this solution instead of PD mapping by other Network Licensees.

- Learnings about how the developed system compares to other pre-fault systems e.g. Pre-Fix and how they can be integrated.

- Could be used by Network Licensees to inform roll-out of a pre-fault system, in comparing and contrasting different pre-fault systems and how they can be used in conjunction.

- Development of the business case for the methodology developed in this project to be rolled out at scale, including projected equipment and operational costs compared to the current BaU standards.

- Could be used by Network Licensees to justify rolling out this solution.

N/A

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. Networks must explicitly mention similar projects that they have considered and how these differ.

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

We have identified that this project addresses a similar problem to the projects 'Pre-Fix' (NGED) and 'HV Feeder monitoring to pre-empt faults' (UKPN). However, the method for addressing the problem is significantly different to these projects to avoid unnecessary duplication. The scope for this project has also been circulated with other DNOs ahead of registration and reviewed against other projects registered on the Smarter Networks Portal.

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

This project aims to develop a methodology that doesn't exist within BaU activity or within our existing supply chain. This project will be the first trial of the proposed end-to-end fault management system, as the enabling technologies are still in development or are completely novel, and as such it has an unproven business case. Running this project through innovation funding will allow this novel system and method to be developed in a risk-managed way.

This project relies on the research, development and demonstration of several enabling technologies. In particular, research and development will proceed on two novel, street-level devices - a Pulse Injection Generator (PIG) capable of locating induced events and a sensor mat capable of locating events in the cable section beneath it. Pulse injectors are BaU for cable tracing, however pulse injectors for event location marking by ToF methods are novel. Development and demonstration will take place on three technologies arising from previous innovation projects Create Innovation Solutions have been involved in – 3-phase HV cable sensors, Precision Event Timing Units (PETUs) and a webserver for data collection and analysis. These technologies have been validated in test/lab environments, but are unproven on a real network, which NGED will facilitate through running this project.

Relevant Foreground IPR

All IPR generated during this project will be shared in line with the standard NIA IPR terms. This is expected to include:

- Reporting on the design, development and testing of novel sensing devices.
- Reporting on the design of the components and architecture of the Pre-fault detection system.
- Trial outputs from the network trial planning in NGEDs region.
- Test Plans
- Sensor and whole system specification and design documents.

Data Access Details

All project findings will be published on the ENA Smarter Network Portal, and on NGED's website.

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

The low technology readiness level (TRL) of the technologies being developed and unproven methodology means that this project is unsuitable for BaU activity.

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 risks associated with this project are too high to justify business funding without NIA support. Specifically, the low TRL of the proposed technologies poses technical risks; development could be affected by component availability, compatibility or EM interference, and there is a possibility that the conceptual system cannot work adequately in the field. The NIA funding is necessary to allow testing in lab, trial network and live network environments, this will enable networks to understand if this system could work in the future, at which point it would be suited to BaU funded investment.

This project has been approved by a senior member of staff

☑ Yes