Energy Networks Innovation Process

Annual Project Progress Form

The voice of the networks

Notes on Completion: Please refer to the NIA Governance Document to assist in the completion of this form.
Do not use tables.

Step 1 - Initial Project Details

Project Title

HV Pinpoint

Project Reference

NGED_NIA_074

Nominated Project Contact(s)

Scott Ball

Project Start Date

03/24

Project End Date

10/25

Scope (15000 Characters max)

The scope of this project is to pursue the research and development of a set of low TRL technologies, tested in the laboratory, trial network and live network environments, which may be used as an integrated pre-fault management system utilising novel methodologies for pinpointing HV pre-fault defects on NGED's underground network. The method uses sensors capable of detecting phase-to-phase and phase-to-earth pecking events, which do not 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 are also being developed for validating and pinpointing defects. The system is planned to be applicable to three-ended circuits and not rely on techniques using test vans, providing an alternative to partial discharge 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 partial discharge mapping. Additionally, this new capability is intended to unlock the full benefits of a pre-fault capability in general. These benefits are accessed by using the approach to provide a pinpointed defect location from a broader location given by Pre-Fix methods or, potentially, as a stand-alone system. The benefits are captured through a reduction of fault management costs through operational savings and reduced interruptions incentive scheme (IIS) penalties, improved customer service through reduced customer interruptions (CIs) and customer minutes lost (CMLs) as well as 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 and use of the system required for the expected large uptake of low carbon technologies (LCTs) such as electric vehicles, solar panels, battery storage and heat pumps.

The project is being delivered via the following work packages which, in most cases, are aimed at supporting key steps in the planned pre-fault management system.

- Work Package 1 (WP1) – "Detect". This is focused on the detection and recognition of pecks (defined as pecks, fractional cycle bursts and micro arcing all less than 50 amperes with line-to-earth, line-to-line, and other phase combinations). These alterations to the electrical waveform or characteristics are caused by damage or decay of a cable and often lead to its failure.
- Work Package 2 (WP2) – "Locate". The "locate" key step is concerned with the identification of the location of network events (for example, pecks).
- Work Package 3 (WP3) – "Validate". The need to adjust for a range of uncertainties that can occur during the process for locating network events has been recognised and this work package is intended to respond to this using novel technologies.
- Work Package 4 (WP4) – "Pinpoint". Once a locational match has been achieved via the work undertaken in the earlier work packages, it must be confirmed that the location is that of a pecking event (especially as there may be more than one on a circuit) and not from other sources. This is being addressed again by using a novel technological approach.
- Work Package 5 (WP5) – "Integrated system". This is focused on the integration of the various elements of the solution into an integrated whole.
- Work Package 6 (WP6) – "Project Management and Reporting". This work package provides support and assurance to the project.

These work packages are being supported by work to develop a set of enabling technologies as follows:

- Wraparound three-phase online cable sensors (known as *KlikPower* sensors) which combined with PETUs - see next bullet point - are capable of detecting phase-to-phase and phase-to-earth pecking events (which include pecks, fractional cycle bursts and micro arcing all less than 50 amperes with line-to-earth, line-to-line and other phase combinations).
- Cable end precision event timing units (PETUs).
- A website and database (called *Kestrel* - previously sometimes known as *Phoenix*).
- Two completely novel street-level devices - a pulse injection generator (PIG) for location validation and a sensor mat for pinpointing.

Objective (15000 Characters max)

- 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 endboxes, 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

Success Criteria (15000 Characters max)

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

- Demonstration of the 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 the repeated accuracy of the approach 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. This means, for example, that the approach is 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.

Step 2 - Performance Outcomes

Performance Compared to Original Project Aims, Objectives and Success Criteria

Details of how the Project is investigating/solving the issue described in the NIA Project Registration Pro-forma. Details of how the Project is performing/performed relative to its aims, objectives and success criteria. (15000 Characters max)

HV Pinpoint was mobilised following contract signature in March 2024 in line with the original project plan and timescales. By March 2025 it was around two-thirds through its planned project lifetime. Hence, whilst many activities have been started, their completion is scheduled for later in the project, or the learning that has been achieved has suggested amendments to the approach which are likely to obtain better outcomes.

Shown below are selected examples of progress made against the objectives and success criteria of the HV Pinpoint project during the reporting year ending March 2025:

OBJECTIVES

Objective 1 - Develop 3-phase online HV cable sensors capable of detecting phase-to-phase and phase-to-earth pecking events, which don't require CTs

- Wideband HV current and event *KlikPower* sensors are being used in the HV Pinpoint project, the first version of which had extensive pre-project testing on the live Holywell 11kV network at Loughborough University. The second version of the sensor – developed as part of HV Pinpoint and identified as KPII - was confirmed as suitable for deployment on live networks and for use with a wide range of three core 11kV cables and switchgear following extensive laboratory and trial network testing.
- It was confirmed that data on load, switching, multi-cycle and fractional cycle events can be captured by the KPII sensor. It was also shown that the sensors have a much higher frequency resolution than can be achieved with conventional 50Hz current transformers and that such events can be compared with results from conventional power frequency ring main unit current transformers and with high and wideband frequency current sensors.
- Embedded event extraction tools produced at Loughborough University (a project sub-contractor) to detect and analyse fractional cycle events within captured waveforms were evaluated and enhanced. These algorithms have provided encouraging results in identifying these networks events from the large amount of data produced by sensors and collected by the PETU's. Assessing the embedded signal extraction approach on PETU captured high resolution waveforms provided particularly good matches.
- Pulse events seen by the KPII sensors were captured, accurately time-stamped by PETUs in relation to GNSS timing, and sent to the webserver for analysis.
- This objective is substantially met although further improvements may be made as the project continues.

Objective 2 - Develop a Pulse Injection Generator (PIG) which can be used to validate event location

- Pulse injection, detection and distance to event measurement was successfully tested at National Grid's Deeside Centre for Innovation.
- Outline requirements and design studies for the development of the pulse injection generator system were prepared.
- Work has started on the design of the field trial prototype.
- Progress on meeting this objective continues.

Objective 3 - Develop sensor mat which can pinpoint events from street level

- Fractional cycle events have been detected by a proof-of-concept sensor mat system 750mm above event locations and their positions visualised by a further set of tools developed by Loughborough University. This followed intensive kit preparation and testing in the laboratory.
- Progress on meeting this objective continues.

Objective 4 - Test the developed devices in lab, trial network and live network environments

- There have been substantial amounts of testing of the *KlikPower* sensors, PETU's, and early prototype sensor mat in the laboratory and on a trial network whilst the PIG concept was tested at National Grid's Deeside Centre for Innovation.
- Live network testing is planned on NGED's 6.6kV network in Coventry in the next phase of the project.
- Progress on meeting this objective continues.

Objective 5 - Combine the developed devices into an integrated system which can be used for end-to-end pre-fault management

- Most of the work on this work package are scheduled for later in the project but the successful enhancement of the Kestrel website and data base is an essential enabler for this activity.
- The data from the various systems is collected by the secure Kestrel webserver with a comprehensive set of data visualisation screens and remote control of settings and pulse injection tools.

Objective 6 - Develop a system which works on three ended circuits

- The HV Pinpoint approach HV current has been designed to operate on three ended circuits.
- It is intended to demonstrate this on live NGED circuits in Coventry or elsewhere.
- Progress on meeting this objective continues.

Objective 7 - Develop system in a way which can be installed and operated non-invasively, without needing to break apart switchgear endboxes, which can be used with a range of cable/switchgear types

- *KlikPower* sensors can be installed non-invasively on a wide range of cables and switchgear types and installation circumstances.
- The project has shown that there is a need for a set of different sized sensors to deal with the widely differing circumstances that are encountered on operational networks.

Objective 8 - Develop a portable system not reliant on test van techniques

- HV Pinpoint does not rely on test van techniques and is portable to different locations so this objective is on track to be met..

Objective 9 - 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

- Work on this objective will continue in the next phase of the project.

SUCCESS CRITERIA

Success criteria 1 - Demonstration of the 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.

- Ongoing - Many of the building blocks necessary to meet this criterion have been achieved as outlined above. However, full demonstration of the approach awaits installation of the sensor devices and other equipment on live operational circuits where pecking events are occurring.

Success criteria 2 - Demonstration of the repeated accuracy of the approach on a live system, including circuits with high background harmonic noise and switching noise.

- Ongoing - See success criteria 1

Success criteria 3 - 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.

- Ongoing - See success criteria 1

Success criteria 4 - Demonstration of reporting to a standalone data system with web interface.

- Ongoing - This has been demonstrated on a trial network, but full validation awaits HV Pinpoint installation on a live operational network.

Success criteria 5 - Demonstration of non-invasive live installation and operation of equipment on NGED's network, which is widely applicable. This means, for example, that the approach is effective on a range of HV cable types and switchgear.

- Ongoing - Trialling, surveying and other activity has demonstrated that *KlikPower* sensors can be non-invasively installed on a range of cable and switchgear types and installation circumstances hence indicating that the approach can be widely applicable. However, as previously, full validation awaits HV Pinpoint installation on a live operational network.

Success criteria 6 - Production of optimised user and design requirements for the each of the prototypes developed as well as the whole system.

- The work to meet this success criteria will be undertaken towards the end of the project.

Success criteria 7 - 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.

- Ongoing - Whilst the work undertaken so far contributes to this improved understanding, further work to meet this success criteria will be undertaken towards the end of the project.

Summary

The HV Pinpoint project has already met several of the objectives and success criteria outlined above notably that sensors can detect pre-faults events of all types, that data can be reported to a standalone data system with web interface, and that non-invasive live installation and operation of equipment on NGED's network can be achieved. Further validation of the achievement of each of these criteria is continuing and progress with the others is scheduled during the rest of the project's lifetime.

Required Modifications to the Planned Project Approach During the Course of the Project

The Network Licensee should state any changes to its planned methodology and describe why the planned approach proved to be inappropriate. Please confirm if no changes are required. (15000 Characters max)

Whilst the overall planned project approach has been robust, it has been necessary to amend the sequence of some of the activities and make several other changes. However, this did not change the underlying technical approach or the scope of the overall project.

Issues that needed to be taken account of included:

- Replanning certain activities because of the lack of availability of resources and facilities with consequential programme management implications resulting in some tasks being delayed whilst others were brought forward.
- Securing manufacturing start slots becoming more challenging leading to additional overseas sourcing.
- Initial testing on a trial network revealing issues that needed to be resolved before device installation on operational networks could be undertaken delaying progress and reducing resource availability for other tasks.
- Using time limited access to a testing site which resulted in the postponement of other activities.
- The recognition of the broad range of approaches used for connecting cables to cable endboxes and ring main units and the difficulties that this may cause for sensor installation meaning that additional sensor types needed to be designed and produced.
- The prevalence of triplex 11 kV cables and their separated cable termination arrangements on modern switch gear was greater than expected. This led to additional work to better understand the challenges that this presents in both detecting and measuring earth fault currents from such arrangements leading to some delays and again reducing resource availability for other tasks.
- Additional resources and time were needed to survey for trial installation a range of potential sites on a set of prioritised 6.6 kV and 11lV circuits with a wide assortment of switchgear and cable types again causing delays and limiting resources for other tasks.
- Developing a range of sensors for larger cables sizes, and also for spaces shorter than were originally expected.

Whilst dealing with these issues has meant that live network device installation has occurred later than originally planned the impact on the overall timeline of the project is likely to be much more limited and, as yet, no changes to the overall completion date have been made.

Lessons Learnt For Future Projects

Recommendations on how the learning from the Project could be exploited further. This may include recommendations on what form of trialling will be required to move the Method to the next TRL. The Network Licensee should also state if the Project discovered significant problems with the trialled Methods. The Network Licensee should comment on the likelihood that the Method will be deployed on a large scale in future. The Network Licensee should discuss the effectiveness of any Research, Development or Demonstration undertaken. (15000 Characters max)

As the project is still ongoing learnings are still being generated. These will be documented in the next annual progress report. Nevertheless, a learnings log is being maintained, and this already contains items in respect of the tests undertaken at the UKPN Sundridge Training Centre in August and September 2024 and those done at the National Grid Deeside Innovation Centre in December 2024. These learnings included that:

- a broad range of live data could be collected using an updated *Klikpower* sensor, other equipment, and the *Kestrel* website but refinements were needed.
- pulse injection from the PETU pulse generator via the Klikpower sensor was demonstrated and pulses observed at other network locations.
- a proof-of-concept pulse injection and mobile reception system can be used to detect injected signals at a depth of 750mm or more for at least 300m along a cable using a simple battery powered injector pulsing at approximately 1Hz. The distance at any point along the route can be established by time of flight compared to a reference timing signal. The features and systems necessary to achieve the necessary measurement accuracy were identified.
- a proof-of-concept sensor mat system can detect fractional cycle type events of 50 Amperes when located 750mm above known event locations.

Further learnings relating to the sensor mat planned to be used for pinpointing events, issues resulting from the use of the HV Pinpoint approach with triplex cables, experience gained from installing *KlikPower* sensors and PETU's on live networks, and other aspects of the project are expected to be documented.

As well as updated learnings the next annual report will also cover recommendations on next steps including what further development and trialling (if any) needs to be undertaken, what barriers need to be overcome, and how commercialisation of the approach can be pursued.

Outcomes of the Project

When available, comprehensive details of the Project's outcomes are to be reported. Where quantitative data is available to describe these outcomes it should be included in the report. Wherever possible, the performance improvement attributable to the Project should be described. If the TRL of the Method has changed because of the Project this should be reported. The Network Licensee should highlight any opportunities for future Projects to develop learning further. (15000 Characters max)

As this project is still ongoing it would be too soon to provide comprehensive details of the project outcomes at this stage. These will be documented in the next annual progress report. Progress so far is described above.

Reports are being produced as the project proceeds and, so far, four have been completed as follows:

- Inception Report (May 2024)
- Report on detecting pecking events at typical depths with a "mat" of field sensors (September 2024)
- Report on tests on HV cable circuit with created events at Sundridge and related work (January 2025)
- Summary of work carried out during the proof-of-concept stage of the project, including the results from location validation testing (February 2025)

Further reports will be produced as the work of the project progresses.

Step 3 - Outputs And Implementation

Data Access Level & Quality Details

A description of how any network or consumption data (anonymised where necessary) gathered in the course of the Project can be requested by interested parties. This requirement may be met by including a link to the publicly available data sharing policy. (15000 Characters max)

Relevant data generated during the project will be made available at nationalgrid.co.uk. Further details will be provided at a later stage.

Foreground IPR

A description of any foreground IPR that have been developed by the project and how this will be owned. (15000 Characters max)

Standard Network Innovation Allowance intellectual property (IP) terms were agreed for this project and are being applied to all IP generated by it.