Energy Networks Innovation Process Project Close Down Form

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
Pre-Fix

Project Reference
NIA_WPD_060

Project Contact(s)
Greg Shirley

Project Start Date

10/21

Project End Date

03/24

Scope (15000 Characters max)

This project seeks to overcome the barriers to wide-spread High Voltage (HV) pre-fault capability represented by vendor tie in and proprietary software.
This project utilises HV pre-fault capture capable devices from different manufacturers to demonstrate how they can all contribute to a common data platform. This project also demonstrates how certain existing network devices such as power quality monitors, protection relays and Low Voltage (LV) monitors might also help contribute to HV pre-fault detection in addition to their basic functions. This project is also developing dashboards and reports that enable a consistent policy driven approach to be implemented across an organisation.

Objective (15000 Characters max)

The objectives of this project are to:

- Develop and validate a process to enable pre-fault capable devices from different manufacturers to contribute information onto the same platform.
- Develop and validate processes to enable pre-fault information to be drawn out of this platform.
- Develop and validate standard reports that enable consistent and effective pre-fault policy driven decision making to be made in an operational environment.

Success Criteria (15000 Characters max)

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

- Demonstration of how to gather and then utilise data from existing NGED specification equipment in the pre-fault data chain, including protection relays and power quality monitors.
- Demonstration of how pre-fault information from diverse devices can be gathered in a central location.
- An application guide for how, where and when to deploy different pre-fault equipment.
- A user interface to present pre-fault data in a manner that is useful, consistent and meaningful to operational users.
- A prototype operational protocol for how to leverage technical applications into operational outcomes.

Step 2 - Performance Outcomes

Performance Compared to Original Project Aims

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)

Performance against our project objectives is as follows:

- **Develop and validate a process to enable pre-fault capable devices from different manufacturers to contribute information onto the same platform – COMPLETED**
  - Common disturbance information platform (C-DIP) has been defined, developed and tested, with devices feeding in pre-fault and post fault information.
  - Proven that PQMs can be used to provide waveform disturbance data into the C-DIP platform.
    - **PQ monitors** needed to be retrofittable within existing 11kV panels within the Primary substation to monitor the 11kV data feed from 33/11kV transformers. The monitors triggered on network disturbances to record wave forms associated with post-fault and pre-fault activity. For the purposes of Pre-Fix, the voltage and current analogues from PQ monitors, and the events they recorded, were used to estimate impedance to defect (whether that be post-fault or pre-fault).
    - 17 PQMs were installed across the East Midlands and South West licence areas. During the early stages of the trial, it was observed that overcurrent triggers filled up the memory buffers but triggers based on current and voltage distortion rather than overcurrent allowed more discriminatory noise rejection.
    - In the later stages of the network trial, a direct trigger method was developed between the PQ monitors and Cable FPIs installed within the feeder breakers. The PQ monitors recorded waveforms when the cable FPIs triggered on pre-fault events. This allows the PQ monitors to detect pre-fault waveforms with the same sensitivity as cable FPIs.
  - Proven that smart FPIs can be used to provide waveform disturbance data into C-DIP platform.
    - **Smart FPI Installations** in total the project team installed 210 RTUs within the East Midlands and the South West licence areas. The device availability was improved from 65% up to >95% during the project with the release of a new BETA firmware.
    - **Cable FPIs** need to be retrofittable to existing 11kV Ring Main Units within Secondary Distribution substations and Feeder Breaker panels within Primary Substations to monitor the 11kV data feed from 11kV feeders. These devices detected and remotely communicated the passage of fault and pre-fault current through the network location where the FPIs were installed. Cable FPIs triggered on network disturbances to record waveforms associated with post fault and pre-fault activity.
    - **OHL FPIs** needed to be retrofittable to existing 11kV overhead line circuits to monitor the 11kV data feed from 11kV feeders. These devices detected, locally indicated and remotely communicated the passage of post fault and pre-fault current through the network location where the FPIs were installed.
  - Proven that relays can be used to provide waveform disturbance data into C-DIP platform. More information can be found within our CIRED 2023 paper ‘Delivering the benefits from a common disturbance information platform to prevent unplanned outages’. Within the project we have shown how COMTRADE (Common format for Transient Data Exchange) files can be manually extracted

from existing relays and uploaded onto the C-DIP. Further engagement would be required with relay manufacturers to understand the changes required to ensure that they are able to trigger pre-fault activity.

- Completed bench testing of the pre-fault capability of other third-party devices. Waveforms captured by the PQMs and Cable FPIs during the network trials were used to bench test feeder automation RTUs, to test their capability to capture both pre-fault and post-fault waveforms. These devices are able to trigger during post-fault and multicycle pre-fault events but require further setting alterations to be able to trigger sub-cycle pre-fault events.

- Produced and published equipment settings philosophy document outlining the setting requirements to enable devices to be pre-fault and C-DIP ready. This includes recommended file format, device sampling rates and pre-fault and post-fault triggers.

▸ **Develop and validate processes to enable pre-fault information to be drawn out of this platform – COMPLETED**

- A system of prioritisation has been developed with dashboards to communicate this information. The dashboards display a matrix of event information over time associated with each substation. The timeline browser dashboard allows a drill-down to view event grouping initially over a 28-day period with 1 day grouping, then a 7-day period with 3-hour grouping, then a 1-day period with 30-minute grouping. The matrix also provides the distinction between pre-fault and post-fault events allowing the user to filter the matrix depending on their analysis priorities.

- Events are classified as Pre-Fault/Post-Fault based on binary triggers from smart FPIs and presented in a dashboard showing event types over time.

- Feeders with high pre-fault activity were screened to filter out noise and load pickups, allowing for easier analysis of distinct events. This was done using a Fourier series analysis of the waveforms uploaded to iHost by devices in the field and a rule-based algorithm that considered signal to noise ratio and waveform RMS during the capture time period.

- We have developed a waveform classifier using AI that can classify observed waveforms in to archetype groups. This is used to screen feeders for waveform anomalies that we believe are indicators towards failure.

- Calculators for impedance to fault for pre and post fault events have been developed and have been integrated into network models and maps. This allows the user to view automatically generated distance-to-fault information on networks which have been integrated into iHost. Moreover, the user can manually override the distance-to-fault plots by reanalysing waveforms and replotting the distance-to-fault result.

- Calculators for the I^2t and impedance of an event have been developed. This allows the relative intensity of pecks to be compared across different sites and at the same location across different time horizons. These calculations formed the basis of a feeder pre-fault watchlist.

- Validated pre-fault detection and location predictions using comparisons with post-fault locations, partial discharge mapping and helicopter patrols.

▸ **Develop and validate standard reports that enable consistent and effective pre-fault policy driven decision making to be made in an operational environment - COMPLETED.**

- Standardised reports for trial device activity have been implemented and regularly update users with a list of events that have occurred since the previous report.

- Summary reports for trial device activity between a selected date range have been developed which allow users to quickly identify all events within the date range and download the waveform data for each event in a chosen format.

- A wireframe for a feeder watchlist was produced. This details all activity from monitored feeders and highlights feeders of interest. The feeder watchlist allows users to rank feeders of interest through different pre-fault indicators. The project also validated pre-fault detection and location predictions from these feeder watchlist reports through comparison with fault locations and using partial discharge mapping.

Performance against our project success criteria is as follows:

- **Demonstration of how to gather and then utilise data from existing NGED specification equipment in the pre-fault data chain, including protection relays and power quality monitors – ACHIEVED**

  - We have shown how to gather and utilise information from smart FPI's and Power quality devices. Benchtop testing was completed with secondary automation RTU devices and the ingestion of waveform data from relays was demonstrated.

  - We have gathered information from relays located at primary substations and used this during the distance to fault process to cross-check Power quality device waveform captures.

  - We corroborated post fault information recorded by the trial devices with NGED fault reports in order to account for already present reclose/protection equipment activity.

  - We also corroborated pre-fault information recorded by the trial devices with partial discharge monitoring, helicopter surveys and confirmed post fault locations.

- **Demonstration of how pre-fault information from diverse devices can be gathered into a central location – ACHIEVED**

  - Different suppliers were engaged to verify that suppliers can meet the Pre-Fix compatibility requirements.

  - Equipment supplier workshops were organised – suppliers were presented with a settings philosophy that includes minimum requirements and were invited to provide feedback on integration.

  - Data from trial devices has been ingested and processed centrally within the C-DIP and subsequently presented in a user-friendly format.

  - Data from trial devices have been integrated with datasets such as network impedance models in order to provide operational outputs such as distance-to-defect.

  - A paper has been published as part of the CIRED conferences showing the process for integration of data from other sources like CROWN and PowerOn.

- **An application guide for how, where and when to deploy different pre-fault equipment – ACHIEVED.**

  - Device installation techniques have been produced for various pre-fault equipment types.

  - Equipment settings philosophy document published.

- **A user interface to present pre-fault data in a manner that is useful, consistent and meaningful to operational users – ACHIEVED.**

- The implemented dashboard (event timeline browser) captures events by trial devices classified as Pre-Fault/Post-Fault based on binary triggers from smart FPIs and presented in a time-block graph showing event types over time.

- The event timeline browser groups events that have occurred within a given time frame on devices installed along the same primary substation/feeder in order to provide a user-friendly experience when looking to analyse an event.

- The event timeline browser also allows users to locate system-wide disturbances as well as local feeder/primary grouped devices.

- A wireframe feeder watchlist was produced to provide insight into all pre-fault activity on monitored feeders. This allowed the ranking of pre-fault activity by various indicators to analyse time-to-failure metrics of pre-fault anomalies.

- **A prototype operational protocol for how to leverage technical applications into operational outcomes – PARTIALLY ACHIEVED**

  - Trial escalation fits to confirm pre-fault locations (provided by distance-to-prefault algorithm) could provide the outcomes needed to both prove functionality and have assisted in development of protocols for the handling of pre-faults identified by technical processes.

  - Methodologies for validating pre-fault predictions have been defined and tested including run-to-failure, partial discharge and helicopter patrols (for OHLs). However development and testing of additional validation methodologies is required.

  - Operational procedures for mitigating the risks associated with a pre-fault defect becoming a post-fault interruption to customer supplies have been outlined but not fully implemented.

Required Modifications to the Planned Project Approach

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 were required. (15000 Characters max)

There were no major changes to the project delivery plan. There were some changes made to the installation plans for overhead line mounted units. These changes stemmed from the availability of suitable authorised live-line staff in the wake of Storm Eunice. Our response to this was to replace some of the planned live installations with planned shutdowns. All changes have been contained with our internal change control process.

An extension to the project was approved to March 2024 which increased our scope of learning through allowing monitoring of more anomalies in the trial areas and to refine the accuracy of the distance to fault algorithm.

Lessons Learnt for Future Projects

Describe how the project (methodology, stakeholder engagement etc.) changed, or provided opportunities, from your expectation at the start of the project and therefore could be useful for a future project. In addition, please discuss the effectiveness of the research development or demonstration undertaken. (15000 Characters max)

All of the lessons learnt from the Pre-Fix project and details regarding the results from the network trial have been recorded within the project learning report published on the Pre-Fix project website.

There are a number of areas recommended for further research that can be the subject of future projects including:

- Detection of LV network events using HV network equipment

- Understand 3-phase swells and power quality phenomena exhibited by urban (underground cable) HV feeders which impacted Pre-fault predictions.
- Improving time-to-fail predictions for Pre-fault anomalies
- Improving overhead-line phase-to-earth fault location accuracy
- Increasing confidence in using HV pre-fault information for network interventions and asset management decisions.

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 as a result of the Project this should be reported. The Network Licensee should highlight any opportunities for future Projects to develop learning further. (15000 Characters max)

The outcomes of the project are as follows:

- A detailed specification for the requirements of the Common Disturbance Information Platform
- A user requirements specification document outlining required system architecture, user interface, data processing and visualisation.
- HV distance to pre-fault/fault functional requirements document.
- A waveform classification specification document.
- Equipment settings philosophy document where recommended pre-fault device settings is provided for manufacturers to ensure devices can be implemented into the C-DIP
- A common disturbance information platform developed, tested and validated. C-DIP providing real time pre-fault and post event information.
- Operational and system learning reports from the Pre-Fix trial.

These documents and reports are published on the Pre-Fix project website or available upon request.

Step 3 - Outputs And Implementation

Data Access Level

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. Please include a link to the publicly available data policy. (15000 Characters max)

The detailed reports on the completion of Pre-Fix can be found on the project page on the National Grid's Innovation website: https://www.nationalgrid.co.uk/innovation/projects/pre-fix

To request access to project data, please visit: National Grid - Project data

Foreground IPR

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

Foreground IPR which includes C-DIP implementation and visualisation, distance to fault and distance to pre-fault implementation are embedded within Nortech's iHost product. These features will be licensed free-of-charge to other GB DNOs who wish to implement the iHost software.

The requirements specification for the PreFix devices, the functional specification for the distance-to-(pre-)fault module and the functional specification for C-DIP are published on the Pre-Fix project website.

Planned Implementation

Please describe the next steps to implement this innovation project. What policies and standards need to be updated or created as part of this implementation. (15000 Characters max)

There are several next steps for implementation of the Pre-Fix solution. An expanded trial is planned for additional sites within the NGED network to both fully outline and implement the required policy and operational process changes as well as further prove the business case in other areas of the network.

Two follow-up NIA projects are planned. HI-5 will complete a longitudinal study of pre-fault activity to further refine time-failure predictions, complete laboratory testing of cable and cable joint aging and understand how pre-fault information can be integrated in to health assessments of HV underground cable networks. HV Pinpoint will develop equipment and methodology to quickly and easily determine the exact location of HV anomalies that have been highlighted as of interest in the Pre-Fix system.

Other Comments

Standards Documents

Identify any industry standards that may require updating due to the outcomes or understanding developed from this innovation project. If no standards will need to be updated, please state - not applicable

Not applicable.