DELIVERING THE BENEFITS FROM A COMMON DISTURBANCE INFORMATION PLATFORM TO PREVENT UNPLANNED OUTAGES

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ABSTRACT

This paper describes the development and demonstration of a Common Disturbance Information Platform (C-DIP) that can be used to bring together data from multiple equipment types installed across a wide geographical area and at different voltage levels to detect leading indicators of equipment failure and then localise the defect within high voltage (HV) distribution networks.

INTRODUCTION

Project Pre-Fix is funded through Ofgem's Network Innovation Allowance (NIA) funding mechanism and is running from Autumn 2021 to March 2024 [1].

Pre-Fix is being delivered by National Grid Electricity Distribution (NGED) in partnership with Nortech Management Limited.

NGED is conducting this project with the intention of being able to improve customers' experience of power cuts. This will be achieved by enabling faster restoration and potentially intercepting defects before they occur. Pre-Fix seeks to overcome the barriers to wide-spread High Voltage (HV) pre-fault capability represented by developing alternatives to a vendor tie model in that is associated with proprietary software. Overcoming vendor tie in will mean that NGED can interoperate pre-fault sensitive devices. This interoperability will translate into a lower unit cost to deliver this capability.

This project utilises HV pre-fault capture capable devices from different manufacturers to demonstrate how they can all contribute into a Common Disturbance Information Platform (C-DIP).

This project also demonstrates how existing network devices, such as power quality monitors and protection relays can contribute to HV pre-fault detection in addition to their base functionality. The project is in the process of developing operational dashboards and reports that will facilitate a consistent policy-driven approach to be implemented across NGED's organisation and other GB DNOs.

Key activities during Pre-Fix include:

- Use of trial data from other DNOs to inform platform design and support testing
- Architecture specification for the Common Distribution Information Platform (C-DIP)
- Interoperability specification and setting of pre-fault gathering devices
- Design of common operational user interfaces
- Live trial of devices, platform and reports

The key outputs of Pre-Fix will be:

1. A Common Disturbance Information Platform (bringing information from multiple sources together into a single place);
2. Development and demonstration of Distance-to-Defect algorithms (localising the location of the fault or pre-fault in the HV network); and
3. Development and demonstration of artificial intelligence algorithms to classify faulted components via their electrical signatures at the time of fault and during the build up to the fault.

This paper focuses on Key Outputs #1 and #2. Further information on identifying faulted components via their electric failure signatures can be found in complementary Paper # 10747 "Applying Machine Learning to Power Quality Signals to Detect Component Failure Signatures and Prevent Unplanned HV Outages" (focusing on Key Output #3).

BACKGROUND

The increasing dependency on electricity vectors for heating and transport is going to increase the need to maintain a reliable electricity network, but the cost of delivering reliability needs to remain affordable to customers. Developing a capability to detect leading indicators of equipment failure and then localise the defect enable improvements to reliability to be made. To ensure that this capability is delivered at a low cost, it is essential that low cost devices can be used in the detection and localization function. For this reason, it is essential that a means to ensure vendor interoperability be developed rather than depending on vendor specific head end systems.

NGED addressed the problem by developing a vendor-agnostic data platform that could receive input from network devices, overlay it on network records and deliver standarised reports to system users.

SOLUTION ARCHITECTURE

The conceptual solution architecture for C-DIP is given in Figure 1. Data from various field devices (such as trip alarms, analogue measurements and waveform captures) is fed into a single platform for analysis, event corroboration and benefits extraction. C-DIP supports interfaces to other NGED systems including:

- PowerOn: NGED's Network Management System, providing data such as the real-time status of circuit switches;
- NGED's Geographical Information System (GIS), providing data such as the geographical layout of NGED's HV networks;
- CROWN: NGED's asset database, providing a cross-reference for localising component defects; and
- NGED's Integrated Network Model (INM), providing circuit impedances and network topology.

The field device and integrated system data is processed accordingly to deliver the required outcomes of Pre-fix (determining HV pre-fault and fault locations, quantifying pre-fault activity metrics and informing the priority of preventative actions).

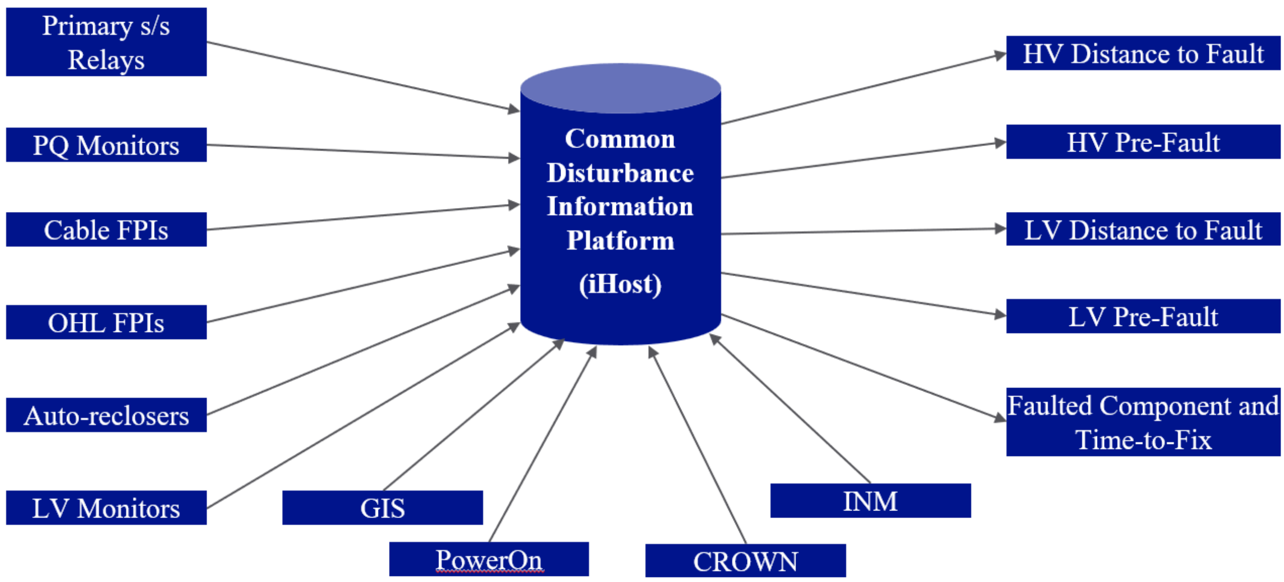

Figure 1: Common Disturbance Information Platform (C-DIP) Conceptual Architecture

C-DIP Field Devices

The Pre-Fix solution make use of NGED's iHost system (a vendor-agnostic platform for data gathering from field devices). The field devices given in Figure 1 and feeding data into C-DIP are described in the sections that follow:

Primary Substation (s/s) Relays

Relays need to fit into (or replace) existing 11kV panels within the Primary substation to monitor the 11kV data feed from 33/11kV transformers. The relays trigger on network disturbances to record wave forms associated with fault and pre-fault activity. Where the capability exists, relays need to generate and remotely communicate to PowerOn impedance to fault information.

Power Quality (PQ) Monitors

PQ monitors need to be retrofittable within existing 11kV panels within the Primary substation to monitor the 11kV data feed from 33/11kV transformers. The monitors trigger on network disturbances to record wave forms associated with fault and pre-fault activity. For the purposes of Pre-Fix, the voltage and current analogues from PQ monitors, and the events they record, are used to estimate impedance to defect (whether that be post-fault or pre-fault).

Cable Fault Passage Indicators (FPIs)

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 need to detect and remotely communicate the passage of fault and pre-fault current through the network location where the FPI is installed. Cable FPIs need to trigger on network disturbances to record waveforms associated with fault and pre-fault activity.

Overhead Line (OHL) Fault Passage Indicators (FPIs)
OHL FPIs need to be retrofittable to existing 11kV overhead line circuits to monitor the 11kV data feed from 11kV feeders. These devices need to detect, locally indicate and remotely communicate the passage of fault and pre-fault current through the network location where the FPI is installed. Where possible OHL FPIs need to trigger on network disturbances to record waveforms associated with fault and pre-fault activity.

Auto-reclosers
Communicating auto-reclosers need to trigger on network disturbances to record wave forms associated with fault and pre-fault activity. Where possible, auto-reclosers also need to generate and remotely communicate to PowerOn impedance to fault information.

Low Voltage (LV) Monitors
LV monitors need to be retrofittable to existing LV distribution boards within Secondary Distribution Substations. These devices need to detect and remotely communicate the presence of voltage on the LV side of the Secondary Distribution Substation in order to help differentiate between an HV and LV network defect.

DISTANCE TO DEFECT

Using data from C-DIP, this section of paper illustrates the benefits that can be gained in terms of more precise fault location for both post-fault and pre-fault scenarios.

Fault Location (Post-Fault)

The post-fault location of C-DIP is illustrated using an urban underground HV cable network as given in Figure 2.

NGED verified the performance of the HV distance to fault algorithm using a standard power quality monitor and advanced fault passage indicators. Two methods (inductive [2] and resistive [3]) were trialled by NGED for defect location. Both methods predicted results for the phase-phase fault that were within 189 metres of the true defect (a failed lead porcelain joint), with one of the methods (the resistive method) being within 20 metres of the defect.

Further refinement of the inductive method (accounting for pre-event loading across the Primary Substation) brought the fault location prediction to within 20-metres of the actual fault location also.

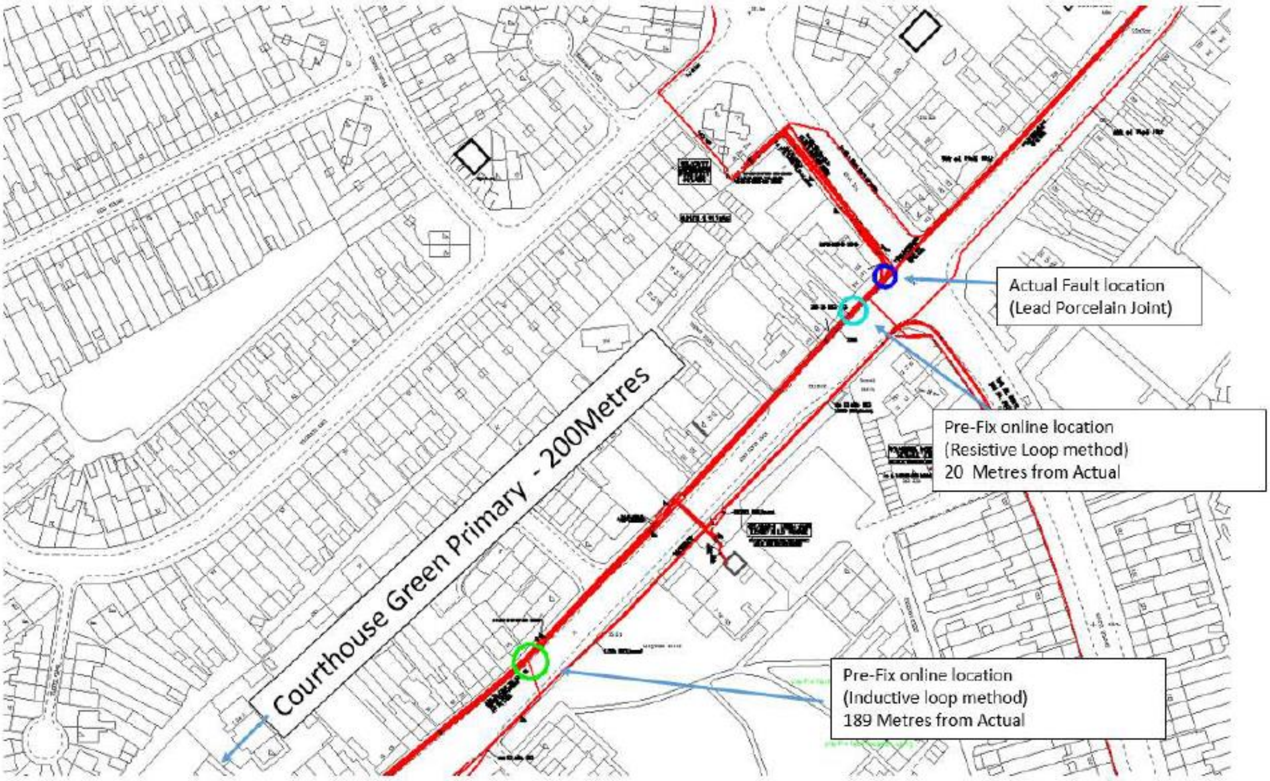

Figure 2: Distance to Defect (Post-Fault) Illustration in an Underground HV Cable Network

Fault Location (Pre-Fault)

The pre-fault location of C-DIP is illustrated using a rural overhead line network as given in Figure 3. Electric disturbances were detected by the overhead line fault passage indicators at 17:52 on 05/01/2023. The disturbance in electrical current was used to determine three locations (each of equal impedance) beyond the overhead line FPIs. The orange circle depicts the logical bounds of the defect search zone.

The red dots mark the three equal-impedance locations within the overhead line network (on three different spurs). The overhead line was patrolled by helicopter on 19/01/2023 and two instances of tree growth encroaching on the overhead line safety clearance were observed (at the locations marked by a black square in Figure 3).

Remedial work was immediately scheduled to remove the tree growth and prevent an unplanned HV outage.

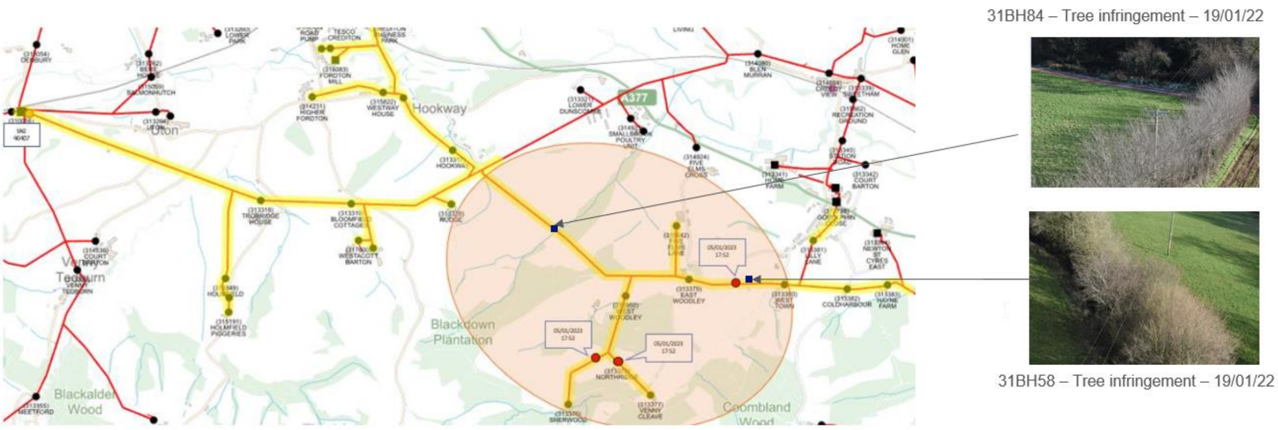

Figure 3: Distance to Defect (Pre-Fault) Illustration in a Rural HV Overhead Line Network

DISCUSSION

The fault location analysis presented in this paper was conducted with a time lag between the point at which the data was acquired within the C-DIP and when the calculations were performed. For business-as-usual (BaU) adoption, rather than routine daily communications and calculations (introducing time delays), the defect waveforms will need to be transferred from devices immediately following the conclusion of the network disturbance. This will allow the distance-to-defect to be calculated in real-time and enable the control room to dispatch field staff, more effectively, to the most likely HV network fault location.

Work is continuing within Pre-Fix to continue validating and refining the distance-to-defect algorithms for a range of different types of fault (for example phase-to-earth and three-phase faults) as well as investigating the characteristics of different HV component failures. In addition, Pre-Fix will continue to expand the number and type of devices integrated within the Common Disturbance Information Platform, informing standard specifications for equipment functionalities.

CONCLUSION

As a result of the C-DIP platform develop, NGED has already been able to begin classifying which circuits have the highest rates of pre-fault activity as a means to indicate risk of unplanned interruptions on individual circuits.

At this stage of development, NGED has also had ability to verify the performance HV distance to fault/distance to pre-fault algorithm. This algorithm was implemented using a standard power quality monitor and advanced fault passage indicators. The post-fault distance to defect algorithm was able to predict the location of the fault to within 20-metres of the actual fault. The pre-fault distance-to-defect algorithm has given NGED early warning of evolving HV network defects. In the example illustration in this paper, tree growth encroaching on a rural overhead line network was observed and remedial works were scheduled to address the issue and prevent unplanned HV outages.

REFERENCES

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[3] IEEE Power and Energy Society, 2014, *IEEE Standard C37.114: Guide for Determining Fault Location on AC Transmission and Distribution Lines,* IEEE, New York, NY, USA, 1-48