Functional Requirements Specification

Product / Job:	J 503
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Version History

Issue	Date	Author	Approved	Comment
0.1	15/11/2021	B Brewin	N/A	Initial draft for peer review
0.2	07/01/2022	S Jupe	N/A	Minor clarifications and expansion to include distance-to-(pre-)fault
0.3	31/01/2022	B Brewin	N/A	Responses to Paul Morris' comments
1.0	15/03/2022	B Brewin	S Jupe	Formal Issue.

Glossary

API	Application Programming Interface
ASC	Arc Suppression Coil
BaU	Business-as-Usual
C-DIP	Common Disturbance Information Platform
CIs	Customer interruptions
CMLs	Customer minutes lost
CSV	Comma separated variable
DMS	Distribution Management System
ED2	The second RIIO regulatory period for electricity distribution
FPI	Fault passage indicator
HV	High voltage
INM	Integrated network model
PQ	Power quality
RIIO	Revenue = Incentives + Innovation + Outputs
RTU	Remote Terminal Unit
SCADA	Supervisory, control and data acquisition
WPD	Western Power Distribution

Contents

Introduction

Pre-Fix is a WPD NIA project which will develop and demonstrate a Common Disturbance Information Platform (C-DIP), allowing equipment from different vendors to be utilised for pre-fault detection and more accurate fault location. The outputs from this project are expected to deliver game-changing performance benefits for WPD (in terms of reduced customer interruptions and customer minutes lost) in RIIO-ED2.

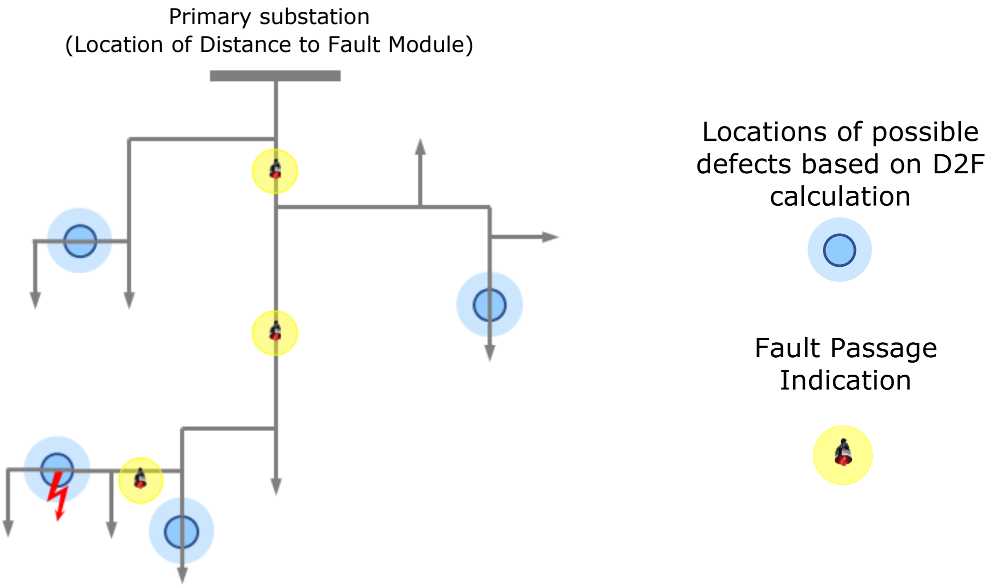
This document forms the basis for the development of a software module (accessible through iHost) which provides a tool to calculate the distance along a HV feeder from the primary substation to the location of a fault (or pre-fault).

For the purposes of this specification, the term 'distance-to-fault' (D2F) encompasses both permanent and transient faults, as well as the location of pre-fault activity. 'Distance-to-fault' is synonymous with 'distance-to-defect'. A defect that results in the tripping of the HV circuit breaker can be classed as a permanent fault. Transient faults are self-healing and result in, for example, auto-recloser operations that do not lock out. Pre-fault activity occurs in the build up to a permanent or transient fault and is characterised by disturbances on the network that are below the trip threshold of a circuit breaker or auto-recloser but are abnormal and point towards the eventual mal-operation of network equipment.

The distance-to-fault module will be used to identify one (or more) location(s) along the feeder from the source to the possible location of the defect.

This system will facilitate the rapid response of field teams to the location of the fault, with the overall aim of reducing CMLs. The pre-fault location detection will inform operational decisions and allow pre-emptive actions to be taken to reduce both CIs and CMLs.

The possible fault locations will be refined to one location using fault passage indication and other available sources of information. An illustration of the concept is provided below.



Primary substation
(Location of Distance to Fault Module)
Locations of possible defects based on D2F calculation
Fault Passage Indication

1 Scope

The scope of the HV distance-to-fault software shall be delivered for the following criteria:

- Defects which result in (pre-fault) disturbances on the network, and (post-fault) interruptions to customers, when protection has operated to clear a fault.
- Resistively earthed systems (in future requirements could be extended to consider arc suppression coil (ASC) systems)

The distance-to-(pre-)fault module will be prototyped and field trials will be undertaken in the Coventry city centre area of the East Midlands, and the Exeter region of the South West. This will deliver trials and learning relevant to urban networks (with predominantly underground cable infrastructure), rural networks (with predominantly overhead line infrastructure) as well as networks characterised by a mixed infrastructure topology.

2 Overall Requirements

These requirements shall be considered mandatory. Any reduction in functionality from these requirements shall be discussed with the customer (WPD).

2.1 Measurement

The module shall return a value of the distance to fault from the substation in both metres (m) [or kilometres (km)] and Ohms (Ω).

2.2 Electrical network

The distance-to-fault module shall be suitable for use on 2 wire and 3 wire 3 phase 6.6kV and 11kV systems. The module shall be suitable for overhead and underground cables systems.

2.3 Online monitoring platform

A centralised online monitoring platform shall host the module and gather data from field RTUs to provide necessary inputs to the module.

2.4 User-interface

The location of the fault shall be presented to the user on a single line diagram, showing the fault search zone as a geographical area on the feeder.

2.5 Control room integration

The Common Disturbance Information Platform (C-DIP) platform shall be capable of direct integration into the control room, should the solution be adopted for BaU.

2.6 Availability

The module should be available 99.9% of the time.

2.7 Auditable decision making

The unit shall log the decision-making process so that indications can be audited and verified.

2.8 Compliance

The supplier shall be able to demonstrate compliance with ISO 9001, ISO 14001, ISO 27001 and ISO 45001 standards.

3 Centralised Hosting Platform

This section outlines the functional requirements of the iHost central monitoring platform, a high-performance server-based solution.

3.1 Field RTU support

iHost shall support DNP3 connections from field RTUs for receipt of unsolicited alarms (e.g. faults, RTU health, etc.) and API for receipt of routine logging data (e.g. load current, voltage, etc.) and general device maintenance (e.g. remote configuration updates, etc.). The platform must support receipt, storage and display of data sampled multiple times per second in line with the highest resolution power quality monitors.

3.2 Data historian & visualisation

The platform shall make a complete set of historical data available to the user with options to download time-series 'snapshot' datasets in .csv format.

3.3 Past events simulation

The platform shall support 'play back' of events from multiple sources (e.g PQ monitor, FPI, distance to fault module output, impedance to fault values from third party sources, etc.) simultaneously to facilitate analysis of the performance of the HV distance to fault module for retrospective fault and pre-fault incidents. 'Bursts' of events, captured simultaneously by different equipment, will be aligned and compared using a user-configured time window for event analysis.

3.4 Prototyping and development

The platform shall provide tools for trending of data and visual display of single line diagrams (schematic and geographical) as a method to display distance-to-fault visually. The platform shall facilitate the 'playing back' of multiple streams of captured events, to review past events in real-time.

3.5 User access

The platform shall support access for multiple users and be accessible from the public internet (for trial purposes).

4 Network Model

A network model of each HV feeder shall be made available to the module.

4.1 Requirements

The impedance model for distance to fault could be derived from various sources (e.g. Integrated Network Model, SINCAL, DINIS, CROWN, EMU)

The requirements for the network model are as follows:

- Geographical topology of the overhead and underground network (component basis)
- Impedance data for overhead and underground conductors:
  - resistance (R)
  - reactance (X)
  - susceptance (B) (optional)
  - conductance (G) (optional)
  - zero-sequence components (optional)
- Switching equipment locations and normally open status
- Primary substation locations
- Secondary transformer locations
- Secondary transformer type (pole, ground mounted)
- Capacitor locations
- Lightning and surge arrestor locations (if available)

4.2 Extent of network model

Network models shall be created on a per substation basis (multiple secondary feeders in one model) such that monitoring equipment which is common to a substation (rather than an individual secondary feeder) can detect possible locations for the fault along several secondary feeders. The network model shall contain secondary distribution transformers which shall be terminated with an LV busbar node.

4.3 Storage format of the model

The network model shall conform to the requirements of the iHost Power Network Analyser module (pandapower .json format). For the purposes of the trial, a software program will be developed to facilitate the automated conversion of SINCAL models to a format suitable for use in the iHost Power Network Analyser, to ensure that network models remain up to date. This will be extended to encompass INM model files as and when these become available with the conversion concept proved as part of phase 1 of Pre-Fix.

4.4 Network configuration

The status of switches, on the network shall be updated from SCADA information in DMS (PowerOn), including:

- open points
- isolators
- feeder circuit breakers,
- bus section breakers
- transformer circuit breakers

Each switch shall have a unique identifier (alias) in the SCADA system, such that the position can be mapped to the network model.

Multiple switch alias' shall be able to be mapped to a single equivalent switch in the impedance model to prevent unnecessary duplication of components where switches are in series between nodes.

The quality indicator for switches shall be reviewed to consider the validity of data if the received value is 'bad-scan', switches can be manually dressed by the control room and this may result in a bad quality state if not correctly configured in the DMS.

4.5 Ownership

Ownership of the network models shall reside with the Innovation team during the project, the Innovation team shall decide on transfer of ownership if adopted as a business-as-usual solution.

4.6 Maintenance

The owner shall carry out periodic and/or reactive maintenance to ensure the models remain up-to-date and valid. The network models shall be as maintenance-free as possible.

5 Distance-to-fault

5.1 Accuracy

The location shall be approximate with a tolerance / radius of search zone assigned according to availability of corroborative information.

5.2 Types of fault

The module shall determine distance-to-fault for earth-fault and phase-to-phase faults, both transient and permanent.

The module shall consider post-fault events, when protection has operated to clear a fault. The distance to fault module will be extended to consider pre-fault events as the database of events is populated through the project (and with data from other sources such as UKPN).

5.3 Field measurements

Measurements and indications shall be obtained from field RTUs and other network equipment either manually (post-event) or online where available.

Measurements could include:

- Fault detection (binary)
- Voltage presence (binary) downstream of the fault location
- Impedance to fault (R and X) (ohms)
- Waveform capture files (COMTRADE)
- Fault current magnitude (A)
- Fault current duration (ms)
- Faulted phase indication (PQ monitor)

5.4 Handling multiple defect locations

The module shall determine all paths along the radial feeder to the possible location(s) of detects from the position of the fault recording, considering multiple branches along the same feeder that could lead to multiple defect locations of the same fault impedance. The fault loop is included in the distance to fault calculation by the relay (fault recorder function) at the primary substation.

5.5 Fault impedance

The module shall make provision for the fault arc impedance to be built into distance-to-fault calculations. It is recognised that arc impedance might not be constant across pre-fault events. This data will be established as the event database is populated and analysed during field trials. E.g tree growth might increase and get burnt away again, or an underground cable defect might change over time with water ingress.

5.6 Distance metric

The distance to fault shall be determined as an ohmic value and a m (or km) value.

6 User Outputs

The module shall generate the following outputs.

6.1 Search Zone / List of faulty equipment IDs

The network models shall be adapted on-the-fly to consider the most up to date network configuration information reported by SCADA.

The search zone shall be defined

Multiple search zones shall be returned where the value of distance-to-fault returns several possible fault locations, example of several branches of one feeder, or across multiple feeders.

Corroborative equipment (e.g. FPIs) shall eliminate possible fault paths where the fault passage has not been recorded between the source and the distance-to-fault location.

6.2 Distance to fault

The distance-to-fault metric shall be given in metres from the substation (or specifically the location of the protection relay).

6.3 Reliability metrics

The module shall provide an indication of the reliability of the of the calculation, using weighted metric derived from the validity of available sources of information.

6.4 Success indication

The module shall indicate whether the calculation of distance-to-fault has been successful after each calculation.

6.5 Auditable decision making

File containing information on decision making including all distance-to-fault locations and paths excluded by AI fault classification and other corroborative equipment.

7 User-Interface

Distance-to-(pre-)fault results will be represented on a map-based system with geographical representation of the network (for field staff operations) as well as SLDs (for dissemination purposes). This is covered in the Pre-Fix UI functional specification.

8 Assumptions

8.1 Network Model

Network data available (and complete) in a common exchange format (e.g SINCAL).

8.2 SCADA Interface

The switch position information from SCADA is assumed to be common in format across the licence areas, indicated by the following (integer) values:

- 5 = closed
- 4 = open
- 0 = no state