Version History

Issue	Date	Author	Approved	Comment
0.1	11/01/2022	A Forster	N/A	Initial Draft
0.2	17/01/2022	A Forster	N/A	Minor changes, Worked Example of Projected Customers, C-DIP Requirements and Device Representation.
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1.0	28/03/2022	A Forster	S Jupe	Finalised version issued

Distribution List

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Glossary

Acronym	Meaning
BSP	Bulk Supply Point
BST	British Summer Time
C-DIP	Common Disturbance Information Platform
GMT	Greenwich Mean Time
GSP	Grid Supply Point

GUI	Graphical User Interface
LV	Low Voltage
PQ	Power Quality
PQM	Power Quality Monitor
RAG	Red/Amber/Green
SN	Smart Navigator 2.0
SLD	Single Line Diagram
UTC	Universal Coordinated Time
WPD	Western Power Distribution

1 Introduction

Pre-Fix is a WPD NIA project which will develop and demonstrate a Common Disturbance Information Platform, 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 background for the data processing required for the proposed iHost Pre-Fix Dashboard.

This dashboard will facilitate faster identification of (pre-)fault activity in the network, as well as diagnosing likely failure chance and decreasing the time required to locate the (pre-)fault in question. This can help to inform decisions about required pre-emptive maintenance of equipment in the context of urgency and affected customer numbers.

2 Workflow

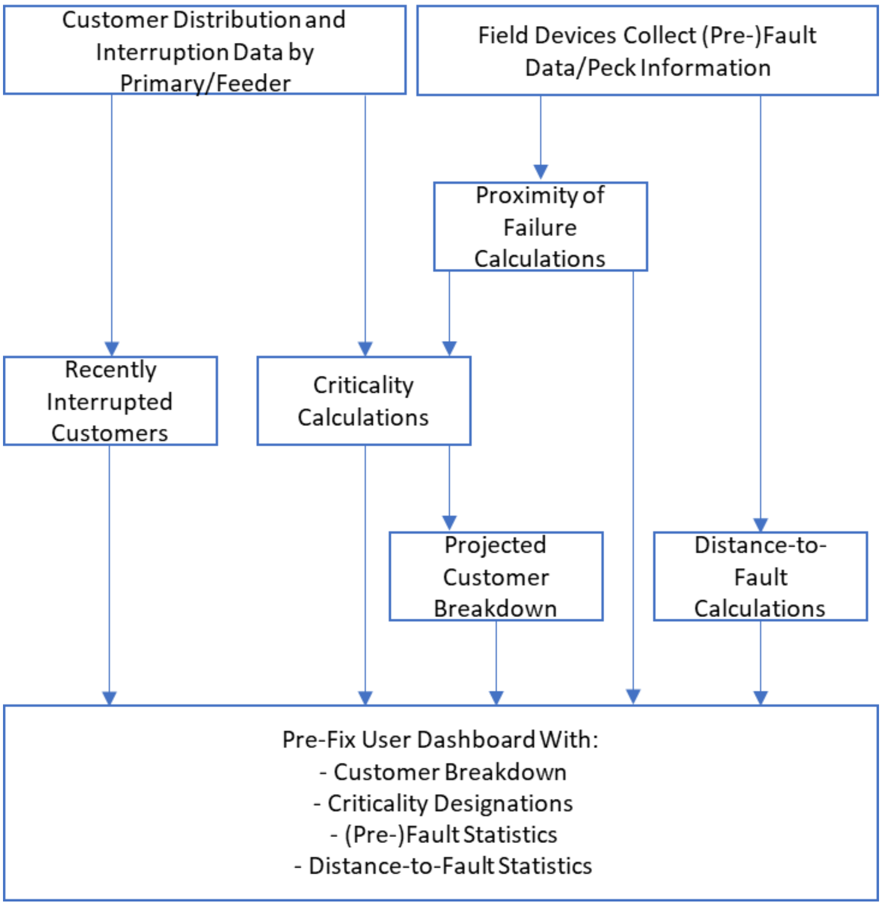

Figure 1 – Workflow diagram

3 Requirements

3.1 Proximity to Failure

The Pre-Faults that have been detected on the network need to be assigned with an individual failure likelihood in the form of Proximity to Failure. This would serve as a quantified level of "risk" associated with the pre-fault.

There are a number of possible inputs into these calculations that could serve as "flags" for the calculations of this likelihood of failure:

- The absolute magnitude of a peck(s). Does this exceed a defined value?
- The relative magnitude of a peck(s). Does the difference in magnitude between a peck and the usual value exceed a defined value?
- The repetition rate of pecks. Does the number of pecks observed during a defined amount of time exceed a defined quantity?
- The duration of the peck(s). Do the pecks which exceed a defined magnitude last longer than a defined period of time, measured in (fractions of) cycles?
- The point on the wave at which the peck occurred. At what angle on the voltage wave did the pre-fault event begin and end?
- Does the peck alter the wave amplitude?
- Which phases were affected by the peck? This could be used to determine which phase an issue is on or be used to track Pre-Fault progression if the number of phases affected rises.
- The correlation of usual load current relative to the ratings of the equipment.

The quantity, type and thresholds of these flags should be configurable by a super user. These defined thresholds can begin as binary flags (or an expanded flag system such as x>, x>>, x>>>) in initial implementation, potentially moving onwards to using weighting for importance once more field data on the effect of each on the imminent likelihood of failure has been collected. Either way, the flags or weightings will rely on the collection of fault progression data as to denote their importance in calculating the chance of failure. The calculated failure rate will then inform the dashboard per pre-fault activity for use in criticality calculations and viewable statistics. As part of these flags, the system will need to have historical counters for pre-fault activity tied to feeders in the network, both to contribute to the repetition rate flag, and to provide evidence that logged repairs have or have not resolved the pre-fault.

The system will also need to be able to use these historical counters to provide a rate-of-change of the flags observed, as a high rate of change indicates a more rapid progression from pre-fault to fault. In the initial implementation, this will be done using logic points in iHost to calculate a rolling window of the number of flags in the last 4 weeks, which would be configurable by a superuser.

3.2 Customer Distribution

The distribution of customers on the feeders (and by extension primaries and depots) will need to be known for the criticality calculations and the customer category breakdowns. In the absence of this data, an estimated number of customers could be used (x customers per y kW of equipment rating, for example).

3.3 Network Grouping

Depots, Primaries and Feeders will need to be grouped in a hierarchical way. For the purposes of the pre-fault project, each feeder will be a child under a single primary, each of which will similarly be a child under a single depot. This will simplify the criticality calculations, as well as the distance-to-fault integration, by limiting the effect each section of the network has on the greater picture.

3.4 Recently Interrupted Customers

One of the datasets required by the dashboard will be the number of customers which have had their service interrupted within a recent period of time. The nominal value for this period would be the last four weeks, but it should be configurable. For full functionality to be possible, these numbers would need to be provided to the dashboard. These customers would be counted in the all-customer datasets but would also be present in a recently-interrupted-specific dataset for use in user analysis.

In the initial proof of concept, this customer breakdown can be assumed based on equipment ratings on circuits that have faulted.

3.5 Criticality Classifications

The different primaries and feeders covered by a depot will need to be categorised into three distinct categories: red (most critical), amber (quite critical) and green (not critical). These categories will be decided by considering the probability of failure at the feeder level due to existing pre-faults, as described in section 3.1.

Initially, the flags can be used to calculate an arbitrary Red/Amber/Green (RAG) score. To calculate the RAG score, the flags described in section 3.1 are used. When an observed event(s) exceeds the flag thresholds configured by the super user, it will contribute a score between 0-10 to the RAG score of the feeder, as configured by the super user. The total RAG score of the feeder is then compared against two thresholds configured by the super user. If the lower of the two thresholds is exceeded, the feeder is categorised as amber criticality. If the upper of the two thresholds is exceeded, the feeder is categorised as red criticality. In general, the higher the RAG score of the feeder, the higher the probability of failure, and so the more critical. Primaries on the system will be classified into red/amber/green based on configurable % thresholds for the feeders under them. If the % of feeders under a primary classified as amber exceed the threshold %, then that primary will be classified as amber criticality, and likewise with red criticality.

To prevent the RAG score of a feeder consistently raising, a period of time should be configurable by the super user. If this period of time passes with no further events/observations, the RAG contribution of the flags for that feeder should be removed.

Later, when data availability is higher, the proximity to failure calculated in section 3.1 will become more reliable and can be used as the basis for these calculations, with a higher proximity to failure indicating a more critical situation. The designations for feeders and primaries will need to remain consistent across the dashboard to allow the user to rank RAG scores according to customer numbers on a particular section of the network (impact of fault).

There are also cases in which it may be relevant to include upcoming weather data in the criticality calculation – especially in the case of upcoming storms or extreme temperature swings that may cause further short-term issues on an already-critical circuit. The minimum functionality required is the ability to log these upcoming events for a certain area/set of devices, which would affect the RAG score of the devices within the area/provided set.

3.6 Distance-to-Fault Integration

One of the dashboard features provides a breakdown of (pre-)fault information at the feeder level. This includes a distance from primary and an impedance statistic, which will require integration with the proposed distance-to-fault system (see appendices for the distance-to-fault specification). There will be distance-to-fault integration for both pre-fault activity, and protection operated defects. Please see appendix 1 for the full specification of this system.

3.7 Projected Customer Numbers

One of the features of the dashboard is a comparison of the red/amber/green breakdown of current customers, and the projected red/amber/green breakdown of customers a configurable period into the future. The nominal value of this configurable period will be 4 weeks. This feature will require logging of completed repair works and would then work to eliminate red/amber designations where this is relevant. This feature will also require some integration with the time-to-failure numbers, as this will allow for future red/amber designations to be correctly calculated. To begin with, these projections would be based on the RAG score of the feeders, but as the datasets surrounding this project become less sparse, the time-to-failure metrics will be more reliable, and the system will be able to be based around them.

Customers that have a time to failure estimated at under 4 weeks (or the configurable period specified) would remain at red criticality in the projection and be tagged in the dashboard with a warning that a fault is imminent if action is not taken.

Worked Example for Projected Customer Numbers

Parameters used in this worked example:

- 1000 Customers in the viewed area.
- Red criticality has been configured by the super user as a feeder having an RAG score of 30 or greater.
- Amber criticality has been configured by the super user as a feeder having an RAG score of 10 or greater.

Current Pre-Faults in the example system:

1. Feeder 1a has an RAG score of 33 = Red Designation. Feeder 1a supplies 30 customers.
2. Feeder 1b has an RAG score of 4 = Green Designation. Feeder 1b supplies 15 customers.
3. Feeder 2a has an RAG score of 1 = Green Designation. Feeder 2a supplies 10 customers.

4. Feeder 2b has an RAG score of 17 = Amber Designation. Feeder 2b supplies 15 customers
5. Feeder 3a has an RAG score of 26 = Amber Designation. Feeder 3a supplies 25 customers.
6. All other Feeders in the area have a RAG score of 0 = Green Designation. The remaining 905 customers are supplied by these feeders.

Our current customer breakdown is as follows:

- Green – 930
- Amber – 40
- Red – 30

Our projected customer breakdown is based on the conditions of the feeders in 4 weeks' time. RAG score will not be changed for these projections, but projected customer numbers will be worked out using the number of customers served by the affected feeder/protection zone(s), and an estimate of how long red/amber criticality feeders take to trip based around previous observations.

In this example, we will assume that red criticality indicates the likelihood of a fault within 2 weeks, while amber criticality indicates the likelihood of a fault in 5 weeks. An example of how the projections may affect the customer breakdown is as follows:

- Feeders 1a remains red criticality but will have a warning to the user that a fault is imminent if repairs are not made.
- Feeder 1b remains green criticality.
- Feeder 2a remains green criticality.
- Feeder 2b was likely to have faulted in 5 weeks, so in 4 weeks' time it will be likely to fault in 1 week and will be assigned red criticality.
- Feeder 3a was likely to have faulted in 5 weeks, so in 4 weeks' time it will be likely to fault in 1 week and will be assigned red criticality.

This gives a projected customer breakdown as follows:

- Green – 930
- Amber – 0
- Red – 70

During the following week, the pre-faults on Feeder 1a, 2b and 3a are repaired, it is verified that no pre-fault activity was observed in the flag relaxation period, and no new pre-faults were seen, leaving a current customer breakdown of:

- Green – 1000
- Amber – 0
- Red – 0

And a projected customer breakdown of:

- Green – 1000
- Amber – 0
- Red – 0

3.8 (Pre-)Fault Mapping

Mapping of the network will be done using SLDs, with the x/y coordinates for each feature using the latitude/longitude of the feature. This approach will allow for a geographical map overlay/layer without the need to create a separate map.

One of the features included is an embedded map of (pre-)fault zones. The distance-to-fault system will have direct influence over the grouping of (pre-)fault activity, allowing multiple nearby events to be corroborated into a single counter of (pre-)fault activity on that section of the feeder. In the case of pre-faults, this will have an influence on the proximity to failure calculations, as it will be the record of the frequency of pre-fault peck activity.

The initial implementation of the mapping feature will use device alarm states to highlight the sections of the feeder which it is possible the (pre-)fault occurred on. It will also display the possible predicted location(s) of the fault as calculated by the distance to fault module. If there is no distance-to-fault functionality available on the section of the network (e.g., no category 1 device at the primary) in which the fault occurred, the mapping will use fault detection from category 2/3 devices deployed on the feeder to filter out and highlight the section(s) of the feeder where it is possible that the fault occurred.

When more information has been gathered about the accuracy of the distance to fault predictions, it will be possible to calculate confidence zones based around the distance to fault predicted locations. When mapping confidence zones for a (pre-)fault, there should be a red zone to denote the predicted pre-fault location with high confidence (80% - configurable by superuser), and an amber zone to denote the total possible zone the (pre-)fault could be located in (99% confidence – configurable by superuser).

As (pre-)fault activity continues to occur on the network, this map will be able to be updated with smaller and smaller high confidence zones, based on the equipment that reports the (pre-)fault activity and their respective positions on the network. This means that the initial (pre-)fault plots on the maps may be vague but will narrow down as the activity continues.

More than one zone will be visible on the map at a time, to represent the (pre-)fault activity happening within the system. Should two (pre-)faults be occurring at similar locations, the map will need to be able to display both zones distinctly, with the ability to temporarily prioritize or hide one of the zones.

3.9 Logging of Repairs

The data processing system will need to have a way for the user to log completed repairs for a feeder/section of a feeder. These logs will cause the counters built up for pre-fault activity in that location to be reset, affecting the criticality calculations, the customer breakdown, the projected customer breakdown, and the pre-fault mapping areas of the dashboard.

If a repair is logged but the issue is not resolved, then the pre-fault will initially disappear, but further pre-fault activity will then create a new counter in the area, giving an indication that the repairs have not resolved the underlying issue. If the repair has partially fixed the issue, further pre-fault activity will be reduced, and the new counter will reflect this while checking flags/calculating criticality.

3.10 Waveform Classification

The data processing system will need to be integrated with the classification system for the purposes of identifying (pre-)fault waveform patterns. This will help to identify the (pre-)fault type and potentially the component(s) that are most likely to be causing the (pre-)fault when provided component location data. As well as this, this system will allow for non-pre-fault indicators to be classified as such, meaning they can be excluded from further scrutiny.

This classification system will also allow the Pre-Fix system to distinguish between different (pre-)fault types happening on a single section of the network, aiding in predicting how many unique (pre-)faults are present. Please see Appendix 3 for the full specification of this system.

3.11 Weather Data Correlation

The system will need to be able to store provided weather data for defined areas with information such as average wind speeds or rainfall measurements. Upon pre-fault activity occurring in an area, the system needs to be able to use this weather data to supplement pre-fault information displayed. Examples of this may include “the pre-fault occurred within x hours of rainfall”, or “the pre-fault occurred when wind speeds exceeded y mph”.

4 System Integration Requirements

4.1 Distance-to-Fault Integration Requirements

The system will need to be able to corroborate the results from the distance-to-fault system with the criticality calculations and customer breakdowns. The system will also need to be able to plot post-fault information based on distance-to-fault metrics. The distance to fault technical specification describes this process and is documented in Appendix 1 (D_003908).

This will allow for a complete display of relevant pre-fault information in the dashboard, including search zones based on degrees on confidence plotted on a geographical map view of the network.

4.2 Device Integration Requirements

The system will need to be able to corroborate data from multiple nearby devices in the field when they see the same (pre-)faults.

Due to the need for grouping events seen by multiple devices, the system will use a configurable window of 3 seconds to correlate events. A window of 10 minutes should be sufficient to capture all of the devices which see a pre-fault event.

(Pre-)Fault events will also need to be grouped by location, to ensure that two devices on completely different sections of the network do not have their (pre-)fault events synchronized just because they occurred at similar times. To do this, further integration with the distance-to-fault module could determine whether it is feasible that the events which occurred in quick succession were within the same area. Events that are not feasibly close to each other will instead be classified as two separate (pre-)faults.

As well as this, the system will need to be able to synchronise this data in order to ensure that the chance of failure and criticality calculations remain consistent.

In addition, the project will inform the criticality of the requirement to have an accurate point in time (such as GPS time) by which all devices feeding into the system are synchronised on a frequent basis.

As with OHL Power Pointer, once NX-44s are proven in the field, the intention of the Pre-Fix project is for NX-44 fault alarms to be integrated within the PowerOn environment to provide maximum benefit to control engineers and field staff.

As a future requirement, the system infrastructure should be able to handle the inclusion of category 1 devices such as relays on feeders as well as upstream at the primary. This would include corroboration of fault information by capable devices to display all possible points calculated via the distance-to-fault algorithm and using fault alarms from category 2/3 devices.

4.3 Waveform Classification Integration Requirements

The system will need to be able to corroborate waveform data from devices in the field via a hierarchy of device importance and classify the type of (pre-)fault present, as well as the component type tied to that (pre-)fault type, if available.

Classification of the (pre-)fault types on the network will allow unique (pre-)fault events to be identified, even if they happen in close proximity (temporally or geographically) to another (pre-)fault, which would otherwise cause the events to be corroborated into one event.

5 C-DIP Requirements

5.1 Number of Systems

The vendor shall supply two separate Pre-Fix systems:

- One production system, deployed at WPD.
- One pre-production system used for testing and development, deployed on a Nortech test system.

Both systems will be shared across all WPD license areas.

5.2 Server Platform

5.2.1 Production System

The vendor shall provide server specifications appropriate for a system with the capacity to communicate real-time with 20 PQMs, 76 SNs, and 170 NX44s, load offline data from LV monitors, and support up to 10 simultaneous users, as per BAU requirements. The server specifications provided shall include the following:

- Processor (number of cores and speed)
- Memory
- Disk space and IOPS
- Network connectivity and bandwidth requirements

The Pre-Fix software shall be capable of running on a virtual machine.

5.2.2 Pre-Production System

The vendor shall a pre-production system with the capacity to communicate real-time with a minimum of:

- 2 PQMs
- 2 SNs
- 2 NX44s
- Relays for bench testing (to be provided by WPD)
- Any other WPD equipment that has appropriate functionality to be incorporated into the C-DIP system (e.g. RMUs with FPIs pre-installed).

It is envisaged that simulators will be used to represent field devices to give greater flexibility with functional testing and also to give an alternative integration mechanism where physical devices are unavailable, or it is not feasible to locate them at Nortech for the purposes of bench test integration.

5.3 Service Availability and Resilience

The Pre-Fix software will include a backup solution with a target recovery time of 5 days.

The availability of the Pre-Fix software services must be at least 99.9% measuring over one month.

The Pre-Fix system shall monitor the general health of the system and raise an alert both in the GUI and via email notification if there are any system issues detected.

5.4 User Interface

The Pre-Fix system shall provide a web-browser based GUI, and without any requirement for installation of additional software on the client machine.

The Pre-Fix system shall support the following client web browsers running on a Windows 10 or Windows 11 desktop or laptop:

- Microsoft Edge (latest and previous stable version)
- Google Chrome (latest and previous stable version)
- Mozilla Firefox (latest and previous stable version)

The Pre-Fix shall support deep URL links to allow linking to specific pages within the user interface from other internal WPD systems.

5.5 Data Model

Acting as a unified platform, the Pre-Fix system shall provide a common model for different types of field device and data and be extensible for supporting additional devices in the future without rewrite of the core functionality.

5.6 Data Integrity

The Pre-Fix system must retain and store any data quality indicators reported by the field devices (such as IEC 61000-4-30 flags from PQ monitors) and display to the user in the GUI.

The Pre-Fix system shall use UTC for all timestamps transferred in communication protocols, where supported by the field devices.

The Pre-Fix system must handle local time changes from GMT/UTC to BST and back without any impact on functionality or service.

5.7 Data Storage and Retention

The Pre-Fix system shall include data management tools and configurable data retention policy to automatically archive and delete data stored over a certain age.

5.8 Communications

The current requirement is that the Pre-Fix system shall be capable of communicating with field devices over an IP network (4G mobile communication with 2G backup). In future, the Pre-Fix system will need to be able to communicate via WPD's planned future radio system.

The Pre-Fix system shall be capable of acting as a time sync source for field devices using either NTP or time sync services available in protocols used to communicate with the field devices.

5.9 Security and Access Control

The Pre-Fix system shall provide the following security and access control functions:

- role-based access control system which allows a system administrator to create user accounts and assign user privileges that are appropriate to a job role.
- lock-out users for a configurable time period when exceeding a set number of failed login attempts.
- encrypt communications to the web-based GUI using HTTPS and using a certificate issued by WPD.
- single sign-on for end-users using integrated Windows Authentication (NTLM or Kerberos).

The Pre-Fix software shall be compatible with the WPD standard Anti-Virus security package.

5.10 Auditing and Logging

The Pre-Fix system shall audit log significant actions performed by users and maintain a record of security related events. The following actions shall be recorded in the audit log as a minimum:

- Failed user interface login attempt
- Attempt to access an unknown URL
- Attempt to send data to the server in invalid format
- Attempt to send data to the server from an unauthenticated session
- Add, remove, or update a user account, including changing a user's privilege level
- Add, remove, or update a device.
- Any change to device metadata.

- Any change to server software configuration, including change in software version.
- Starting and stopping of server software and services.

The Pre-Fix system shall log general communication and diagnostic data to assist with technical support.

6 Field Device Representation

Each field device shall be represented as a separate entity within the Pre-Fix system.

Each device entity within the Pre-Fix system shall be associated with the data from that device and no other devices.

Each device entity within the Pre-Fix system shall support recording data associated with that device as defined in the iHost template for that device type.

iHost monitors devices by serial number, allowing for other information such as location to be stored as metadata. This metadata can be updated where needed (e.g. upon device relocation). In addition, the geo-position of devices is stored in iHost in separate data fields to user input metadata. This too is updated on device relocation.

6.1 Device Connection Arrangements

The Pre-Fix system shall support the range of devices and the device measurement connection arrangements (including configurable fault and pre-fault trigger levels and waveform capture) as described in the Device Capture specification.

6.2 Device Grouping & Hierarchy

It shall be possible to organise device entities into a hierarchical list consisting of groups (folders) and individual device entities within the folders. For example, the hierarchy could be arranged with license areas at the top level, then GSP groups, then BSP groups, then substations, and within each substation there could be multiple device entities:

- License area #1
  - GSP group #1
    - BSP group #1
      - Primary #1
        - Feeder #1
          - Device #1
          - Device #2 etc.
        - Feeder #2 etc.
      - Primary #2
      - Primary #3 etc.
    - BSP group #2
    - BSP group #3 etc.
  - GSP group #2
  - GSP group #3 etc.
- License area #2 etc.

Within the hierarchy, groups shall be allowed to be both parent and child elements, in that a group can sit within another group and may contain one or more groups within it.

Groups may contain one or more device entities. Device entities are child elements only, in that they can sit within any group but cannot contain other elements. Each group and each device entity can only appear in one place in the hierarchy, and no recursive structuring (e.g. group 1 sits in group 2, and group 2 sits in group 1) shall be allowed.

It shall be possible for users to modify the hierarchical list, for example: moving device entities from one group to another, renaming a group, deleting a group.

When the hierarchy is visible as a GUI element, each level within the hierarchy will be expandable (all direct child items will be made visible) and collapsible (all child items will be hidden).

6.3 Device Search

A search function shall be provided to find device entities by name, serial number, installation location or substation name. The search function shall support partial match.

7 System Performance Requirements

7.1 Data Processing Requirements

For the purposes of the Pre-Fix project, the system will be required to take comtrade files collected from devices in the field and convert them into usable data for the dashboard.

A future requirement may be for the system to be able to utilise other protocols currently available on the iHost platform as a means to enable wider supplier appeal.

8 Error Handling Requirements

8.1 Data Processing Requirements

The Data Processing system should be able to provide error codes to be displayed on the dashboard when an error occurs, such as when the input data is missing or unusable.

8.2 Device Communications Dropout/Restoration Handling

When integrated with devices in the field, it is important that the system can continue to corroborate data even when one or more devices has lost communications. When the device(s) restore communications, there should be a check to see if the data for (pre-)faults occurring during the dropout is available, and if so, recalculate the chance of failure and criticality for relevant feeders.

9 Testing Methodology

Following approval of this specification, Nortech will produce a set of test books for the functions and features described in this specification. These will represent the various test cases to validate that the C-DIP system is performing as expected for both system intact cases (e.g., healthy device communications) as well as degradation of inputs to the system (e.g., handling field devices going off-scan and communications restoration).

The trail attainment criteria will map directly to this specification, with pass/fail criteria defined against the range of functions and features described.

For example, when considering the waveform classification feature, the testing would be carried out in the following way (as described in Appendix 3 – D_003960), for all the various waveforms defined in the IEEE report that the system is based upon as well as waveforms that exhibit multiple characteristics and waveform data collected as part of WPD's Pre-Fix and UKPN's DFA projects:

- Providing a known fault waveform to see if the system correctly identifies it.
- Providing a waveform with multiple faults to see if the system correctly identifies multiple faults.
- Providing a waveform with an unknown fault to see if the system classifies it as a different fault type.
- Providing a waveform with no fault to see if the system correctly classifies it as displaying no fault waveform features.

10 Limitations

10.1 Data Availability

The source data for pre-fault to fault progression needed to calculate the weightings and demonstrating the functionality of the time-to-failure/chance-of-failure calculations is not currently available. This would need to be collected in order to fully realise the proposed system. In the absence of source data sets from the field, a series of contrived data sets will need to be used for the initial setup of the system.

11 Points for Discussion/Clarification

- Where is the dataset for recently interrupted customers coming from, and what form will it take? Will be needed for some parts of the dashboard, but origins not yet confirmed.
- Will the projected number of customers include/exclude planned repair works?
- Will the projected customer timeframe need to be configurable?
- How often is recently interrupted customer data updated?

Appendices

Appendix 1	Distance-to-fault Technical Specification (D_003908)
Appendix 2	Pre-Fix UI Functional Specification (D_003959)
Appendix 3	Classification AI Technical Specification (D_003958)
Appendix 4	RAG and Customer Breakdown Worked Example
Appendix 5	Pre-Fix iHost Dashboard Mock-ups Worked Example
Appendix 6	Longfield House Worked Example