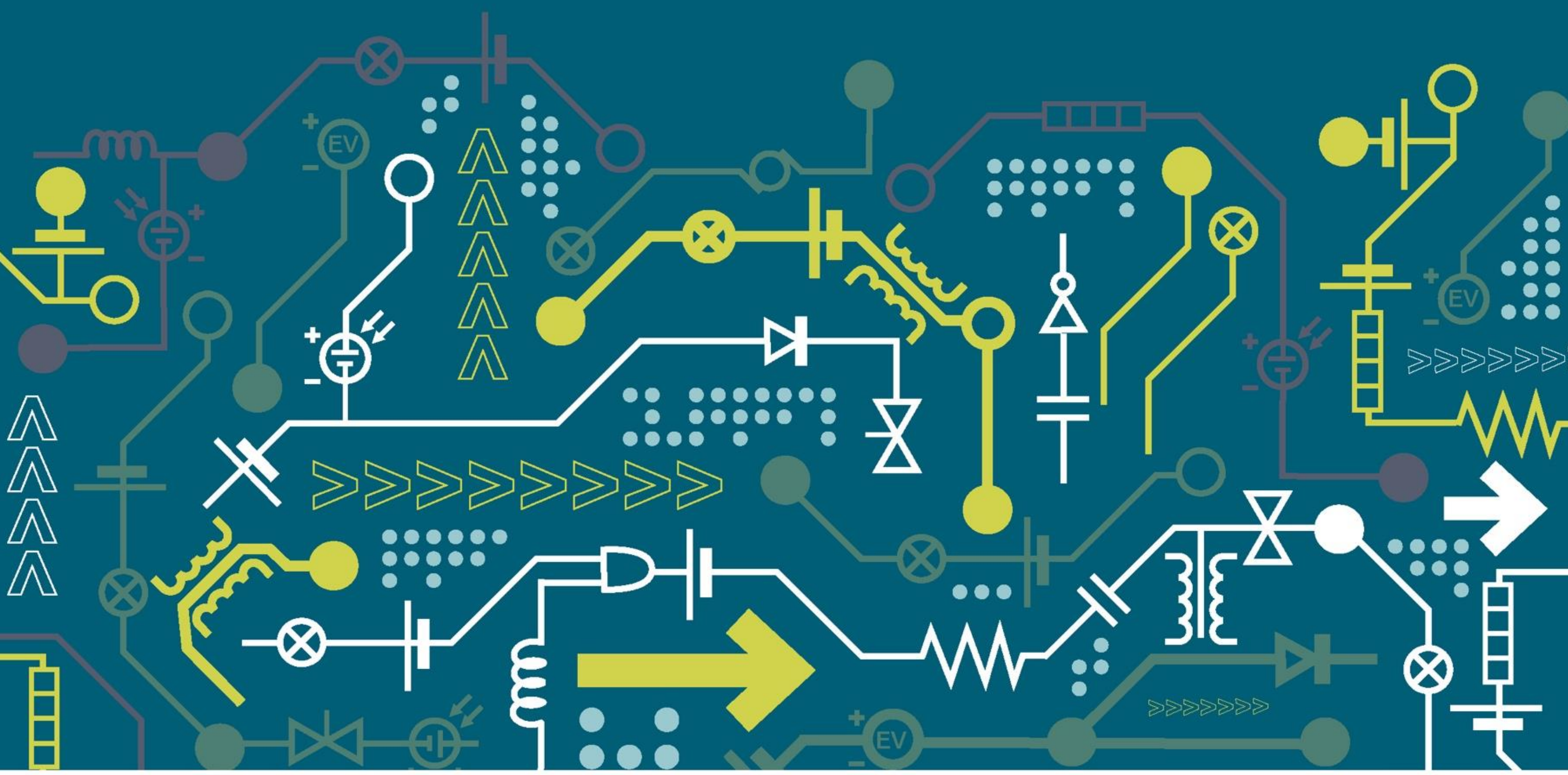
WPD INNOVATION

OHL (Overhead Line) Power Pointer

NIA_WPD_038

Six Monthly Progress Report

Reporting Period: Oct 2019 – Mar 2020



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Version Control

Issue	Date
0.1	06/04/2020
0.2	14/04/2020
1.0	17/04/2020

Publication Control

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Contents

1 Executive Summary

Overhead Line (OHL) Power Pointer is funded through Ofgem's Network Innovation Allowance (NIA). OHL Power Pointer was registered in January 2019 and will complete by January 2022.

OHL Power Pointer aims to trial a device that is capable of self-powering operation to provide real-time voltage, current, directional power flow and conductor temperature information. This information will be used to more accurately assess network operation, such as latent generation output and directional fault detection to more quickly identify the location of faults.

1.1 Business Case

Historically, it has been difficult to capture data in overhead networks, due to the construction of the system and the availability of equipment throughout the network to gather data. As Western Power distribution (WPD) transitions from a Distribution Network Operator (DNO) to a Distribution System Operator (DSO), there is an increasing requirement for localised network monitoring to enable and enhance system operation functions. Moreover, improved monitoring could unlock latent capacity, hence leading to more efficient and economical utilisation of the assets.

The connection of distributed generation across all distribution voltage levels has the potential to back-feed into faults. Currently in multi-branched radial or closed-ring networks it is very difficult to pinpoint the specific location of faults, while OHL fault locations tend to be currently identified via manual visual inspections.

Auto-recloser operations are also recorded manually via visual inspections. This is time-intensive for field staff that could be better deployed on other tasks. Moreover, due to operating temperature uncertainties and limited visibility, the control room currently only makes limited use of probabilistic post-fault OHL ratings, thus potentially underutilising the available circuits.

1.2 Project Progress

This progress report covers progress from the beginning of October 2019 to the end of March 2020.

Nortech Management Ltd. is contracted as a Project Partner, responsible for day-to-day project management and delivery of the project, which is split into three phases:

- Design and build – this is the first phase, which included the selection of trial areas and site locations for the test trials and main field trials, functional specifications of the OHL monitoring device and firmware functionality, and detailed design of the iHost user interface;
- Install and trial – this is the current phase, which includes the deployment of Smart Navigator 2.0 sets on 11kV, 33kV, 66kV and 132kV circuits for monitoring and reporting of data to the iHost platform; and
- Analysis and reporting – this is the third phase of the project which is running concurrently with the second phase, the results from the test trials have been analysed and reported and the learning resulting from each of the Methods is being produced. This phase includes dissemination events and producing the close down report.

Since the project began (January 2019), the trial area and site selection methodology has been established and the Smart Navigator 2.0 device has been specified and developed as the solution for OHL Power Pointer. Test trials have been carried out in the West Midlands licence area, with devices installed on 11kV and 33kV circuits. Devices report into Nortech's iHost monitoring platform periodically (normally every 24hrs) to report operational data from the trial location for the period. Disturbances on the network cause the devices report in at the time of the event, raising alarms where necessary. A total of 50 sets of monitoring devices were installed for the test trials, generating several months of time-series network data.

Nortech has developed a dashboard for the iHost monitoring platform to display information reported from the Smart Navigator 2.0 at trial locations. This includes power flow direction, battery status, device / communications status, conductor temperature, circuit load, post-fault OHL rating and a profile of the daily demand on the circuit. Several interactive network diagrams have been imported into iHost to display a schematic overview of the system and the location of the devices on the network.

Work is ongoing to evaluate the performance of the directional power flow state estimation method using time series data captured from the Supervisory Control and Data Acquisition (SCADA) system. Network models have been built in power systems software and the state estimation module has been evaluated with simple networks to validate performance. This is being scaled up to perform state estimation on the 33kV primary network supplied from Shrewsbury Bulk Supply Point (BSP). This network comprises embedded utility-scale solar generation and conventional synchronous generation which will impact on the direction of power flows around the distribution system.

Site installations are ongoing for the main trials, to date 27 of an additional 50 sets have been installed on 11kV and 66kV circuits. Remaining installations on 33kV and 132kV circuits have been postponed due to events outside of project control, it is not anticipated that this will affect the progression of the project since several months of high-quality data has been captured during the test trials, providing rich datasets for analysis and reporting.

1.3 Project Delivery Structure

1.3.1 Project Review Group

The OHL Power Pointer Project Review Group meets on a quarterly basis. The role of the Project Review Group is to:

- Ensure the project is aligned with organisational strategy;
- Ensure the project makes good use of assets;
- Assist with resolving strategic level issues and risks;
- Approve or reject changes to the project with a high impact on timelines and budget;
- Assess project progress and report on project to senior management and higher authorities;
- Provide advice and guidance on business issues facing the project;
- Use influence and authority to assist the project in achieving its outcomes;
- Review and approve final project deliverables; and
- Perform reviews at agreed stage boundaries.

1.3.2 Project Resource

WPD: Steve Pinkerton-Clark (Project Manager for WPD)

Nortech Management Ltd: Project Partner, responsible for day-to-day project management and delivery of the project:

- Samuel Jupe (Project Executive for Nortech);
- Ben Brewin (Project Manager for Nortech);
- Sid Hoda (Software Development Manager); and
- George Gee (Software Developer).

1.4 Procurement

Table 1-1 details the current status of procurement for this project.

Table 1-1 - Procurement Details

Provider	Services/goods	Area of project applicable to	Anticipated Delivery Dates
Nortech Management Ltd	Day-to-day project management and software development	All	January 2019 – January 2022
Nortech Management Ltd	Smart Navigator 2.0 hardware	Test Trials & Main Trials	Delivered November 2019

1.5 Project Risks

A proactive role in ensuring effective risk management for OHL Power Pointer is taken. This ensures that processes have been put in place to review whether risks still exist, whether new risks have arisen, whether the likelihood and impact of risks have changed, reporting of significant changes that will affect risk priorities and deliver assurance of the effectiveness of control.

Contained within Section 7.1 of this report are the current top risks associated with successfully delivering OHL Power Pointer as captured in our Risk Register.

1.6 Project Learning and Dissemination

Project lessons learned and what worked well are captured throughout the project lifecycle. These are captured through a series of on-going reviews with stakeholders and project team members, and will be shared in lessons learned workshops at the end of the project. These are reported in Section 5 of this report.

2 Project Manager's Report

2.1 Project Background

OHL Power pointer is split into three phases:

- **Phase 1: Design and Build (January 2019 – April 2020)**
  In this phase, the functionality of the OHL Power Pointer solution will be defined for each of the five Methods (directional power flow monitoring, directional power flow estimation, auto-recloser operation detection, directional fault passage indication (FPI) and post-fault rating of overhead lines). The software will be designed and implemented. Network locations will be identified and equipment installation locations selected. In addition, the trials of the various methods will be designed.

- **Phase 2: Install and trial (September 2019 – March 2021)**
  This phase, the Smart Navigator 2.0 equipment (for directional power flow monitoring, auto-recloser detection, directional fault passage indication and post-fault rating determination) will be installed and trialled. Initially, 50 sets of devices will be installed to cover the trials of the various Methods. These devices will communicate to Nortech's iHost system for rapid prototyping of the software and support with the solution design. As part of the main trials, an additional 50 sets of devices will be installed, communicating to WPD's iHost system and the 50 sets installed as part of the initial trials will be transitioned across to WPD's iHost system.

- **Phase 3: Analysis and Reporting (January 2019 – November 2021)**
  In this phase, the results from the trials will be analysed and a report on the learning resulting from each of the Methods will be produced. Results and key learning outputs will be disseminated and policies will be written to facilitate the wider adoption of the OHL Power Pointer solution WPD's business should WPD proceed with Business as Usual (BaU) roll-out.

2.2 Project Progress

The project is currently in the second phase (install and trial), with analysis and reporting running concurrently. The following key outputs and milestones have been completed since the project was registered:

- A functional specification capturing the requirements of the OHL sensor has been prepared, identifying the following core functionality:
    - Directional power flow detection (via direct measurements or combined with a real-time network model to provide state estimations);
    - Directional fault detection;
    - Voltage presence detection (for short-term interruption assessments); and
    - Conductor temperature sensing (feeding in to assessments such as the real-time post-fault rating of conductors).

- Factory acceptance testing of the Smart Navigator 2.0 OHL sensor has been completed at the manufacturer's facilities.

- A trial location methodology has been established and tested prior to the deployment of the Smart Navigator 2.0 solution for field trials, this has been is documented in the trial area and site selection report.

- Test trials have been completed, comprising 50 Smart Navigator 2.0 OHL sensors monitoring 11kV and 33kV networks in the West Midlands licence area, reporting data to Nortech's iHost monitoring platform.

- A detailed design specification for the Smart Navigator 2.0 iHost dashboard (mimic) has been approved and the main software build has been completed. A snapshot of the dashboard available on iHost is presented in
- Figure 2-1. An interactive network diagram displays the position of the Smart Navigator 2.0 devices (and any associated alarms) within the network; this feature is captured in
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- Figure 2-2.

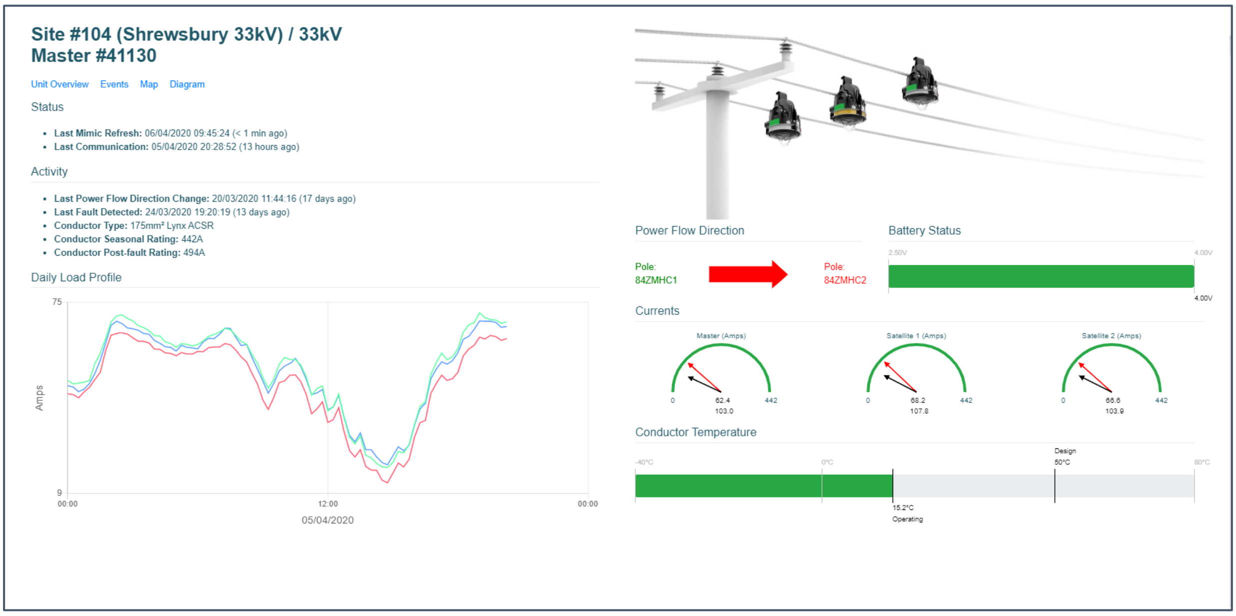

Figure 2-1 - Smart Navigator 2.0 iHost dashboard

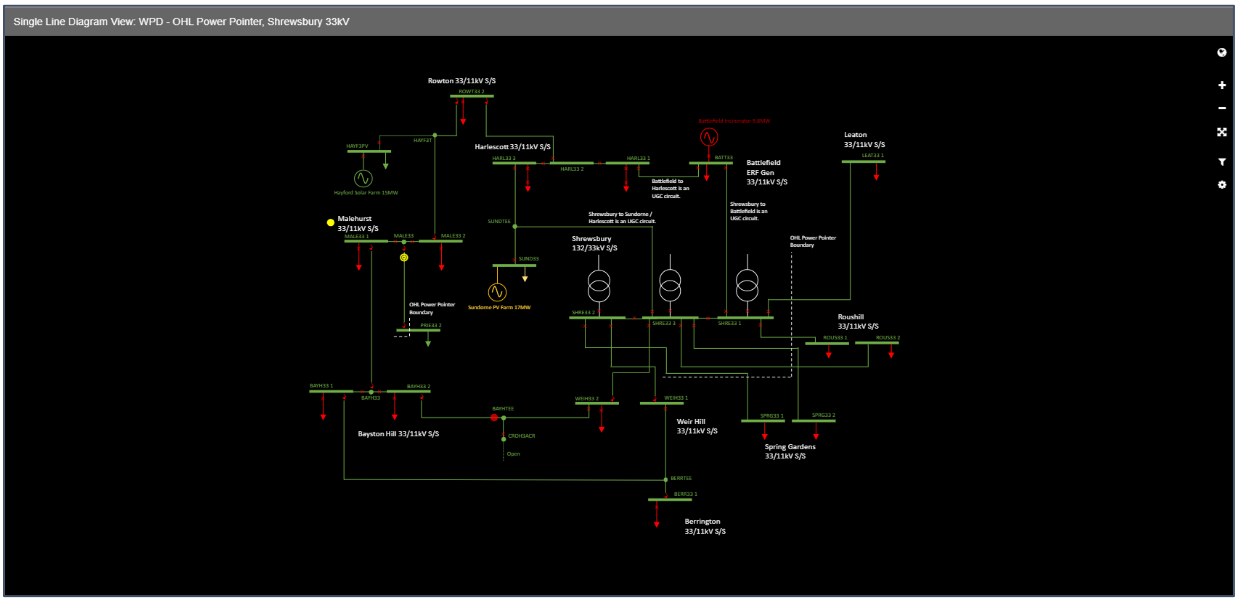

Figure 2-2 – iHost network diagram

The main software build has been completed, the iHost software team will continue to add features as the project progresses and more learning is developed during the main trials.

2.3 Method 1: Directional Power Flow Monitoring

Changes in the direction of power flow have been recorded at several sites during the test trials, each site has been investigated and analysed, and where apparent correlations with wind and solar conditions have been revealed. Other sites network switching has been confirmed with WPD's field teams to understand the cause of the change in power flow directions.

Progress within this reporting period

The detection of power flow direction has been refined in a new release of the firmware for the Smart Navigator 2.0 to enhance performance. Previously the devices reported on change of state from direction A, to a void state, to direction B. The new algorithm eliminates the void state where the magnitude of current is too low to determine power flow direction, resulting in a clean change from 'red' to 'green', and 'green' to 'red'.

The following example from trial Site #224 provides an overview of the performance of the directional power flow detection in the Smart Navigator 2.0.

Site #224 is situated along the 11kV Tilcon Industrial Estate feeder (supplied from Stafford South primary substation), the site monitors a spur identified within the blue boundary in Figure 2-3. Changes in power flow direction have been regularly observed along this spur during the test trails. These changes are caused by intermittent wind generation from a 500kW turbine connected at Lower Hanyards Farm.

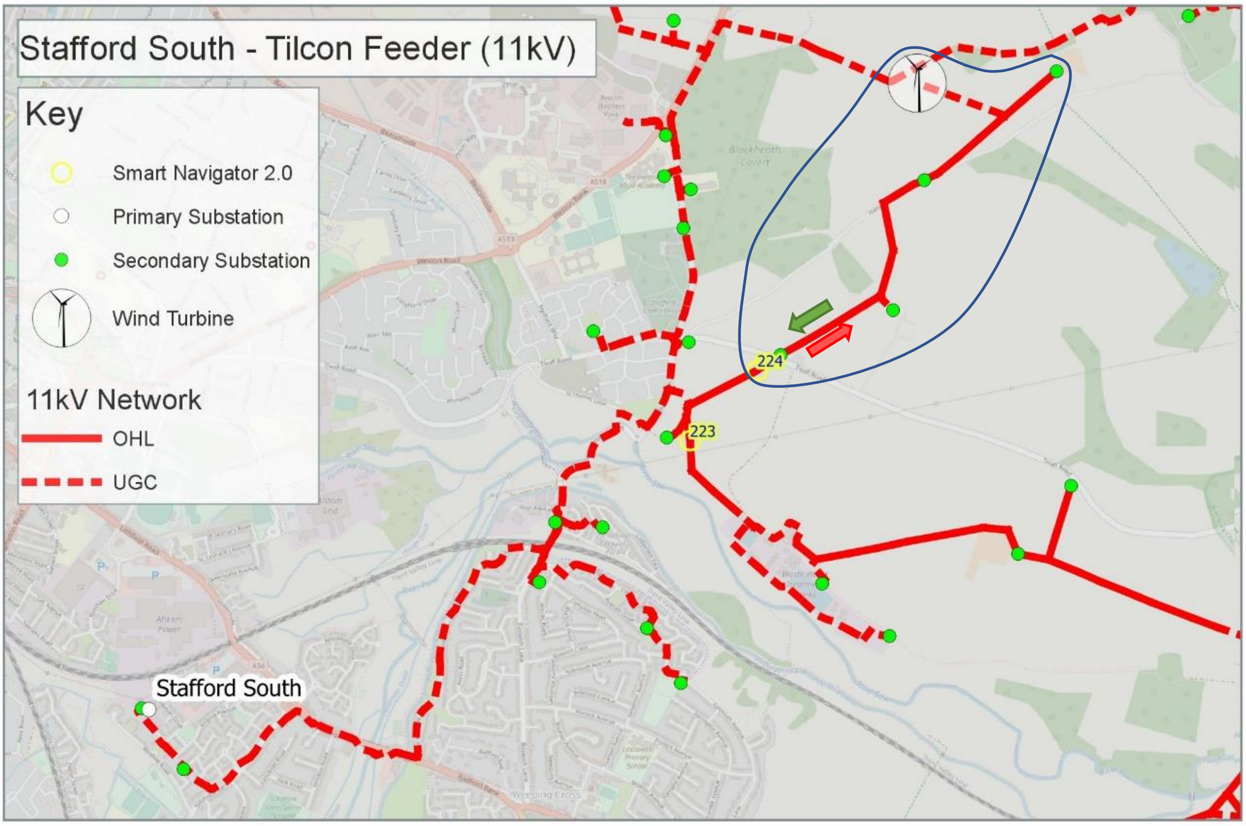

Figure 2-3 – Topological view of Stafford South 11kV feeder

The power flow direction is recorded with reference to the poles at either end of the span upon which the SN2.0 is installed. The pole (or tower) nearest to the SN2.0 is the 'green' direction (86SSTA5 in this case), and the pole (or tower) at the far end of the OHL span as the 'red' direction (86SSTA6 in this case). An aerial view of Site #224 is presented in Figure 2-4. At this site the red direction is indicative of conventional power flow from the primary substation along the feeder towards the secondary substations. The green direction is indicative of power flowing in the reverse direction, with excess wind generation flowing back towards the main backbone of the feeder.

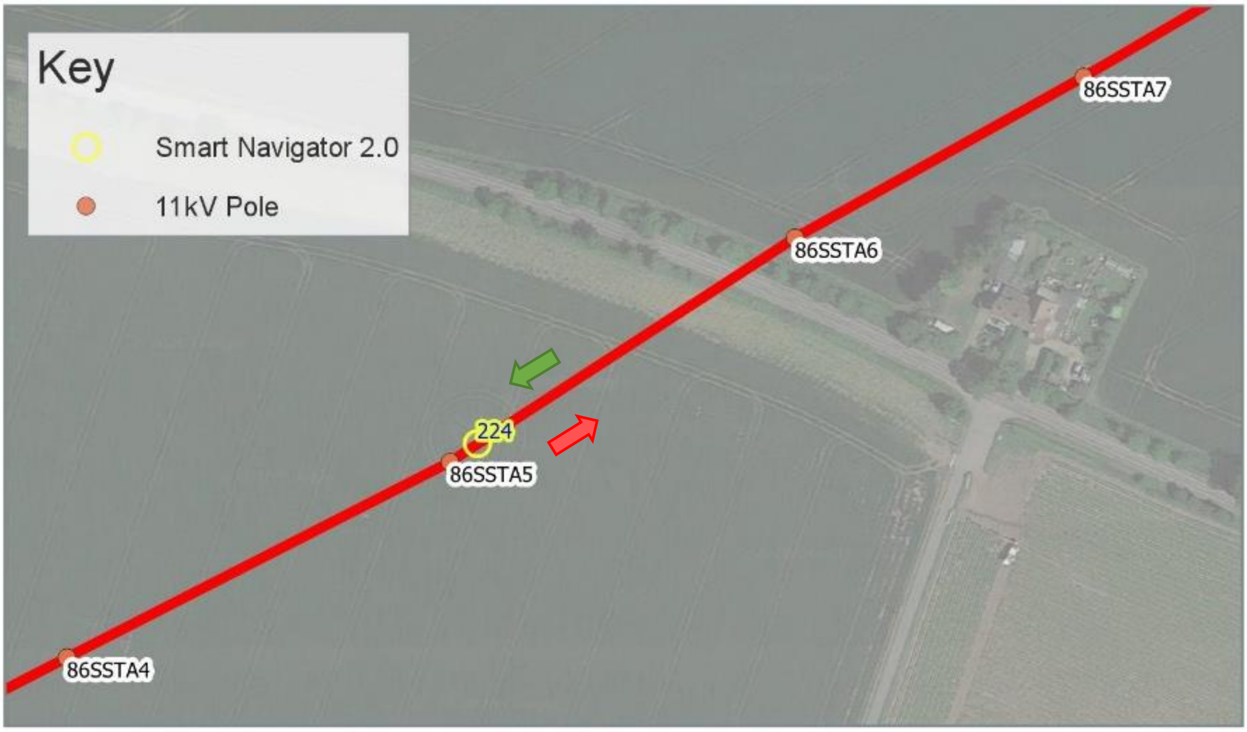

Figure 2-4– Topological view of Site #224 (demonstrating directional power flow convention)

Figure 2-5 presents charts (from iHost) which demonstrate directional power flow at Site #224. Plots of the line current magnitude (amps) and the power flow direction (red/green) are given in the upper and lower charts respectively. The peaks in the line current illustrate the large power flows from the wind turbine during windy days (notably 2nd to 17th January), and the troughs (19th to 25th January) represent calmer days the demand from secondary substation dictates the direction of power flow.

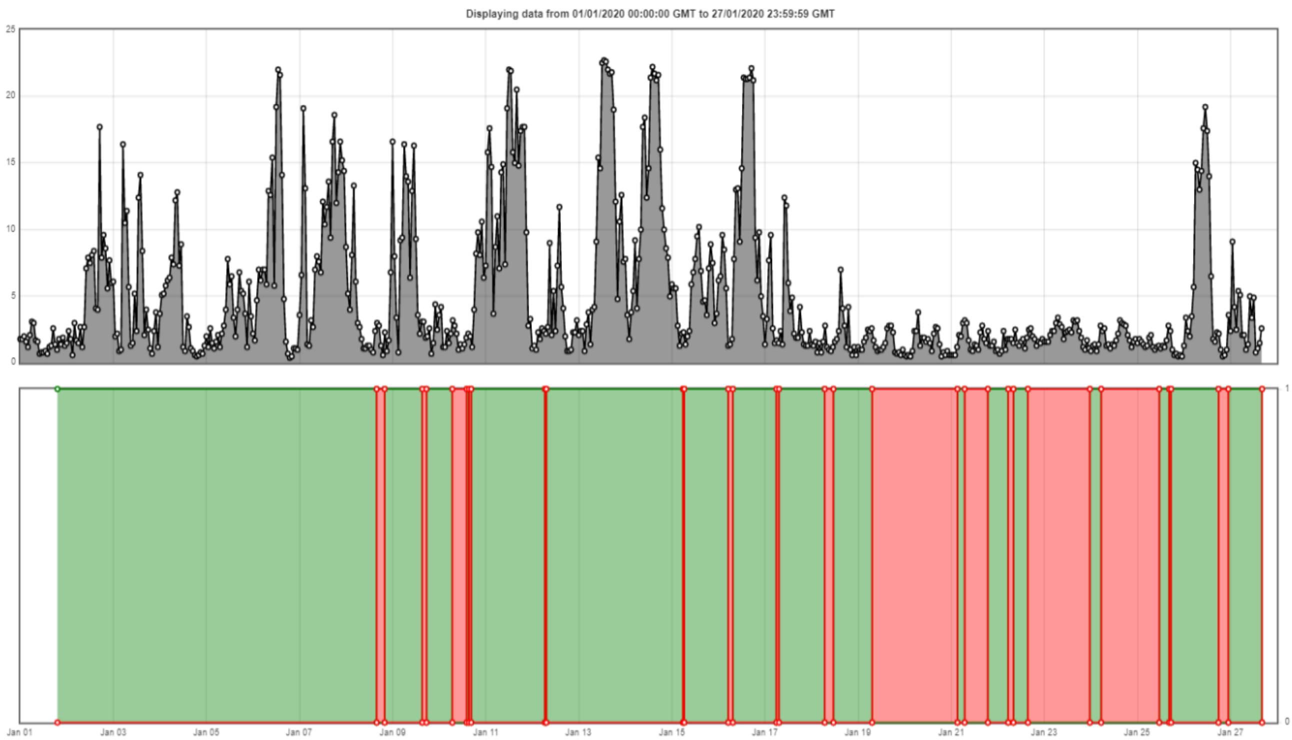

Figure 2-5 – Plots from iHost indicating changes in power flow direction at Site #224

Next steps

The main trials are due to commence in April 2020 and will continue to record changes in power flow direction along feeders. Further installations are planned for 33kV networks with significant quantities of utility scale embedded generation. Analysis of the data should provide a more profound understanding of power flows around distribution networks.

2.4 Method 2: Directional Power Flow State Estimation

Power system state estimation is a method used to provide full visibility of the network based on available measurements. Measurements are typically prone to small errors which can occur in through addition of noise during analogue data transmission or tolerances within the measurement instruments, for example. State estimation offers a method of solving the challenges of network observability by taking erroneous data and calculating a 'best guess' of the present state of the system using weighted linear regression techniques.

Progress within this reporting period

Power system models have been established in Pandapower using data extracted from WPD's Energy Data Hub and impedance models provided by WPD's Primary System Design team.

Pandapower is an open-source power systems analysis toolbox which builds on the Python data analysis library Pandas. The Pandapower state estimation module has been successfully evaluated with a series of scaled-up models and pseudo measurements from load flow results distorted with the addition of randomly generated noise to simulate 'real-world' errors in the data.

Times series data has been extracted from WPD's Time Series Data Store (TSDS) system for transducers located within the Shrewsbury 33kV network, this includes volts, currents, real and reactive power measurements, transformer tap positions, and circuit breaker status'. The TSDS data is a snapshot of all transducer measurements within the extents changing state over a 12-hour period.

The network model for the Shrewsbury network has been configured to accept measurements at network locations to the extent of those contained within the TSDS data. Work is ongoing to test the accuracy of the complete data sets at various intervals prior to performing the state estimation simulations.

The state estimation method will use Smart Navigator 2.0 devices to validate directional power flows through the Shrewsbury network during the main trials. Several devices have been installed for this purpose with more scheduled for installation to obtain complete visibility of 33kV OHL circuits within the Shrewsbury network. This will be used to inform on the number of Smart Navigator 2.0s required to validate the performance of state estimation using SCADA data in distribution networks.

Next steps

Work is ongoing to test the TSDS data in power system models and perform state estimation simulations. The accuracy of the SCADA measurements and orientation of the transducers will be validated against conventional load flow simulations at various intervals in the TSDS period, this analysis will inform on the parameters required to run a successful state estimation simulation.

2.5 Method 3: Detection of Auto-Recloser Operations

Many auto-recloser operations are recorded manually via visual inspections. This is time-intensive for field staff that could be better deployed on other tasks. This method aims to improve the reporting of short-term interruptions to customers and quantify circuit breaker operations to feed into maintenance requirements.

Progress within this reporting period

The SN2.0 distinguishes between short-term (or momentary) and permanent interruptions that occur on the network. Several SN2.0s have been installed downstream of auto-reclose equipment on the 11kV network to observe and quantify reclose operations throughout the field trials.

Between October 2019 to March 2020, 25 short-term interruptions were recorded across all sites. The majority of disturbances were earth faults which were cleared in less than 1500ms.

Table 2-1 – Summary of short-term interruptions detected by SN2.0s during field trials

	Earth fault detected			Overcurrent detected			
Site Number	Master	Sat 1	Sat 2	Master	Sat 1	Sat 2	**Date**
Site #124 (Hereford North)			✓			✓	20/10/2019
Site #154 (Bodenham) *							13/11/2019
Site #124 (Hereford North)	✓	✓		✓	✓		13/11/2019
Site #221 & Site #223 (Stafford South)	✓	✓	✓	✓	✓	✓	17/11/2019
Site #150 (Malehurst)		✓			✓		19/12/2019
Site #150 (Malehurst)		✓					20/12/2019
Site #150 (Malehurst)		✓			✓		25/12/2019
Site #123 (Peterchurch)				✓	✓		30/12/2019
Site #132 (Gnosall)		✓					31/12/2019
Site #130 (Stourport)		✓	✓		✓	✓	09/01/2020
Site #220 & Site #222 (Stafford South)	✓	✓		✓	✓		09/01/2020
Site #123 (Peterchurch)		✓	✓		✓	✓	24/01/2020
Site #123 (Peterchurch)	✓			✓			09/02/2020
Site #123 (Peterchurch)	✓			✓			09/02/2020
Site #149 & Site #150 (Malehurst) *							09/02/2020
Site #147 (Rugeley)	✓		✓	✓		✓	09/02/2020

Site #124 (Hereford North) *							09/02/2020
Site #123 (Peterchurch)	✓	✓		✓	✓		09/02/2020
Site #132 (Gnosall)	✓	✓	✓	✓		✓	11/02/2020
Site #132 (Gnosall) *							16/02/2020
Site #130 (Stourport)	✓	✓	✓	✓	✓	✓	23/02/2020
Site #127 (Harlescott)	✓	✓	✓	✓	✓	✓	11/03/2020
Site #220 & Site #222 (Stafford South)				✓	✓	✓	17/03/2020

* Loss of volts recorded (fault upstream of device)

The detailed design of the iHost dashboard captures the quantification of short-term interruptions and permanent interruptions on an annual basis, this will be introduced as a feature during the main field trials.

Discussions are ongoing with the manufacturer to adapt the algorithm to count circuit breaker operations. The requirements capture has been completed and the manufacturer is currently incorporating the functionality into the next revision of the firmware. The feature will be added to the iHost dashboard once the new firmware has been tested in the field.

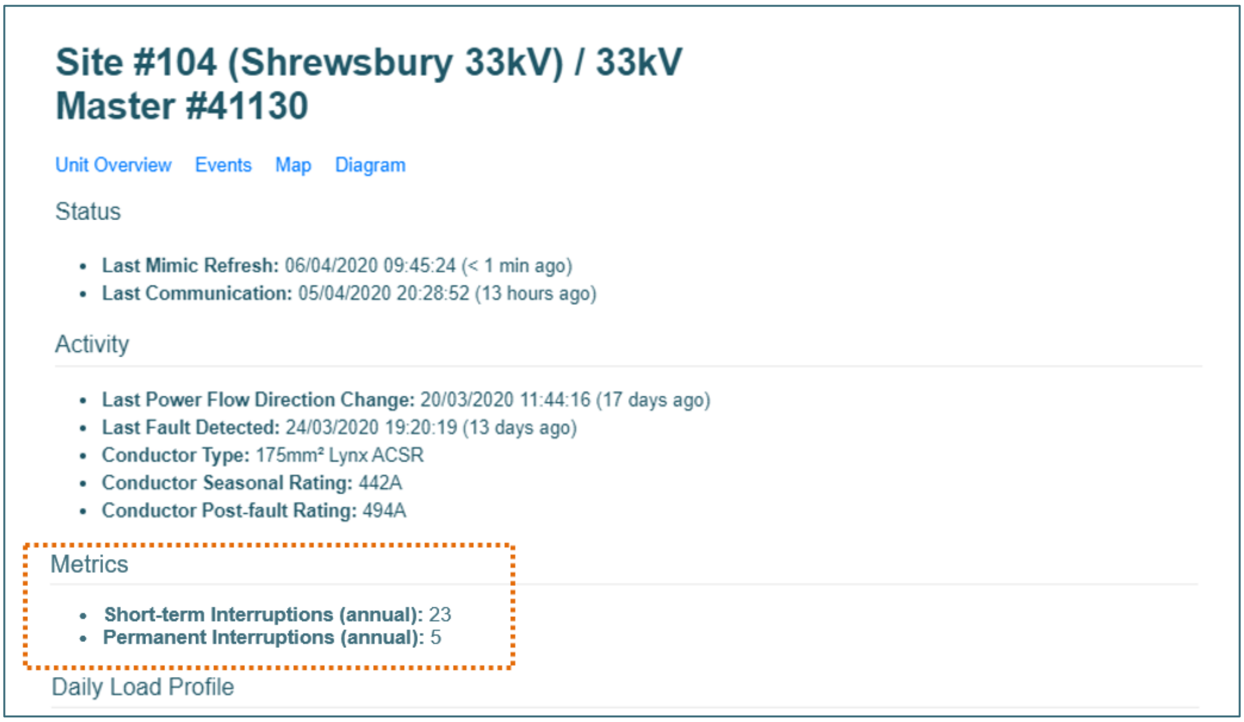

Figure 2-6 – Quantifying interruptions in the iHost SN2.0 dashboard (future release)

Next steps

The manufacturer is testing a new release of firmware for the Smart Navigator 2.0 which will be deployed over-the-air to devices in the field. The new firmware release will implement the facility to monitor consecutive high-speed operations of circuit breakers, enabling the detection of auto-recloser operations. The iHost dashboard will be updated to reflect an annual count of short-term interruptions and permanent interruptions to assist operations teams with evaluation of network performance and asset maintenance requirements.

2.6 Method 4: Directional Fault Detection

The connection of distributed generation, across all distribution voltage levels has the potential to back-feed into faults. Currently in multi-branched radial or closed-ring networks it is very difficult to pinpoint the specific location of faults, while OHL fault locations tend to be currently identified via manual visual inspections. This Method aims to detect the direction of passage of fault currents.

Progress within this reporting period

A total of 90 network disturbances have been recorded by Smart Navigator 2.0 devices during the trials, of which a direction of fault current passage was able to be determined for 35 events. Direction of fault current passage is able to be determined for single-phase overcurrent and earth faults at present.

The majority of 33kV disturbances were attributable to transient overcurrent as a result of auto-reclose events on adjacent circuits within the primary group. Events were confirmed against internal incident reports from WPD which detail information about the cause of the disturbance and any resultant switching or fault clearing activity. The orientation of the device (and consequently fault current direction) is recorded with respect to adjacent poles, green being the direction towards the nearest pole (as noted during installation).

Table 2-2 – Summary of directional fault current detection during field trials

		Earth fault detected			Overcurrent detected			
Site Number	**Fault direction***	Master	Sat 1	Sat 2	Master	Sat 1	Sat 2	**Date**
Site #124 (Hereford North)	Green			✓			✓	20/10/2019
Site #126 (Donnington) *	**Red**	✓			✓			02/12/2019
Site #150 (Malehurst)	Red		✓			✓		19/12/2019
Site #150 (Malehurst)	Red		✓			✓		19/12/2019
Site #150 (Malehurst)	Red		✓					20/12/2019
Site #104 (Shrewsbury 33kV)	Green					✓		24/12/2019
Site #150 (Malehurst)	Red		✓			✓		25/12/2019
Site #132 (Gnosall)	Green		✓					31/12/2019
Site #104 (Shrewsbury 33kV)	Red						✓	11/01/2020
Site #129 & Site #151 (Bodenham)*	**Red**	✓			✓			14/01/2020
Site #148 (Rugeley)	Green				✓			20/01/2020
Site #104 (Shrewsbury 33kV)	Red						✓	01/02/2020
Site #148 (Rugeley)	Green				✓			02/02/2020
Site #104 (Shrewsbury 33kV)	Red				✓		✓	09/02/2020
Site #104 (Shrewsbury 33kV)	Red						✓	09/02/2020
Site #104 (Shrewsbury 33kV)	Red						✓	09/02/2020
Site #104 (Shrewsbury 33kV)	Red						✓	09/02/2020
Site #104 (Shrewsbury 33kV)	Red						✓	09/02/2020
Site #104 (Shrewsbury 33kV)	Red				✓		✓	09/02/2020
Site #104 (Shrewsbury 33kV)	Red						✓	09/02/2020
Site #104 (Shrewsbury 33kV)	Red						✓	09/02/2020
Site #104 (Shrewsbury 33kV)	Red						✓	09/02/2020
Site #104 (Shrewsbury 33kV)	Red						✓	09/02/2020
Site #104 (Shrewsbury 33kV)	Red						✓	09/02/2020
Site #148 & Site #147 (Rugeley) *	**Green**						✓	09/02/2020
Site #104 (Shrewsbury 33kV)	Red						✓	09/02/2020
Site #104 (Shrewsbury 33kV)	Red						✓	09/02/2020
Site #106 (Shrewsbury 33kV)	Green				✓			09/02/2020
Site #104 (Shrewsbury 33kV)	Red						✓	09/02/2020

Site #123 (Peterchurch)	Green	✓			✓			09/02/2020
Site #123 (Peterchurch)	Green	✓			✓			09/02/2020
Site #148 (Rugeley)	Green				✓			09/02/2020
Site #118 (Lydney 33kV)	Green				✓			29/02/2020
Site #123 (Peterchurch) *	**Green**		✓			✓		01/03/2020
Site #146 (Evesham)	Green					✓		03/03/2020

* Events in **bold** indicate a permanent fault, other events were momentary

Next steps

Work is progressing with the manufacturer to expand the classification of direction of fault passage to two-phase and three-phase faults. Fault classification in iHost is currently being trialled and has been captured in the iHost dashboard design.

2.7 Method 5: Conductor Temperature Monitoring

Due to operating temperature uncertainties and limited visibility, the control room currently only makes limited use of probabilistic post-fault OHL ratings, thus potentially underutilising the available circuits. This method aims to implement a post-fault OHL rating algorithm based on real-time conductor temperatures.

Progress within this reporting period

The Smart Navigator 2.0 features a temperature sensor which couples with the overhead conductor once the clamps on the device are engaged. This facilitates direct measurements of the operating temperature of the conductor.

Witness testing undertaken at the manufacturer's facilities in Germany concluded the satisfactory performance of the conductor temperature sensing method in a controlled laboratory environment. The temperature measurements are inputs to the post-fault rating algorithm which determines the post-fault continuous ampere rating for the section of overhead line based on the maximum operating temperature of the conductor.

The post-fault rating algorithm is based on the theory presented in CIGRE Technical Brochure 601[1], Appendix E.3 (Temperature tracking calculation), which has been adapted to include conductor temperature as an input parameter. The methodology considers the adiabatic heating of a conductor to determine the magnitude of continuous current required to bring the temperature of the conductor from its operating temperature to its maximum operating temperature over a user-definable period (10 minutes by default). Figure 2-7 demonstrates the general characteristic of the post-fault rating (blue line) over a week-long period. The data presented is for Site #133 - located on the boundary of Strensham primary substation at the beginning of an 11kV feeder.

[1] CIGRE Technical Brochure 601 (December 2014). '*Guide for Thermal Rating Calculations of Overhead Lines*'

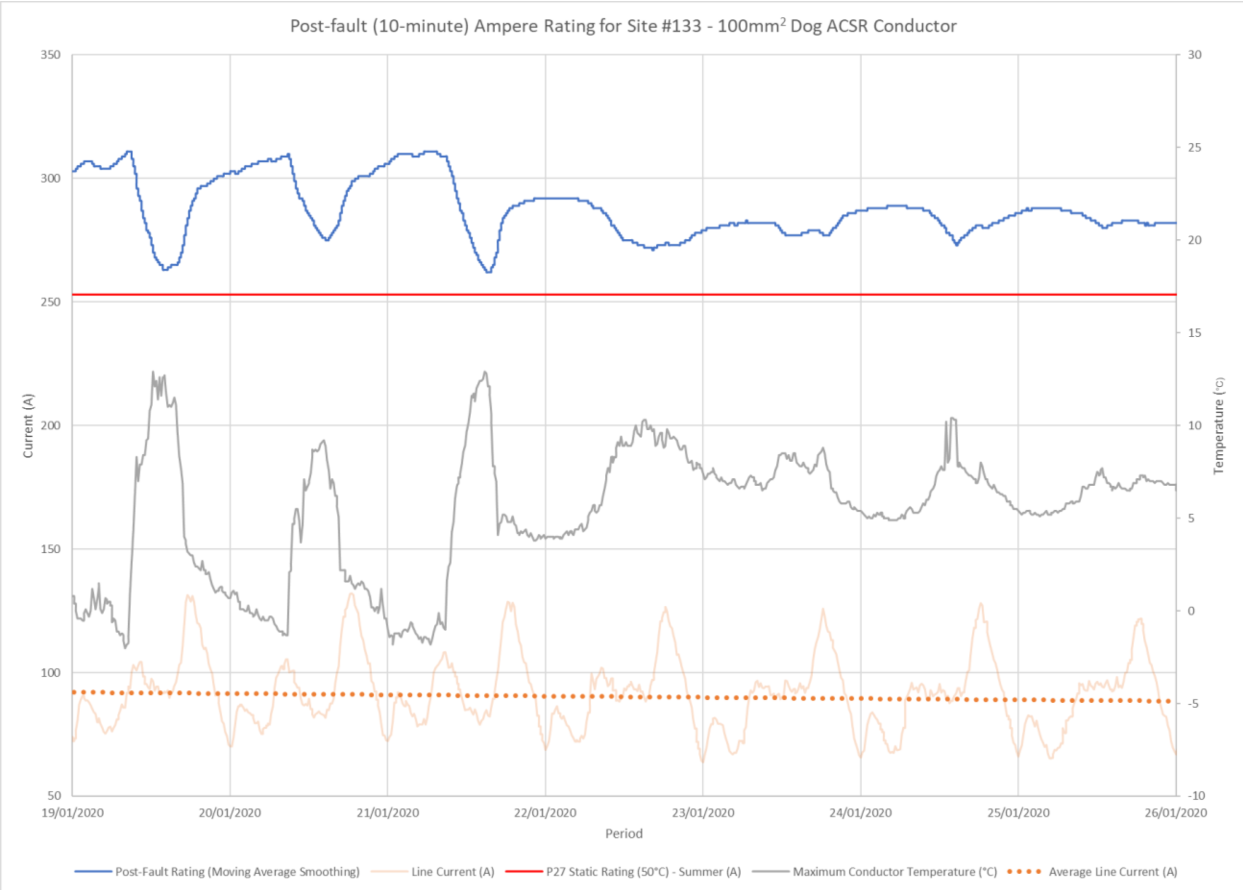

Figure 2-7 – Demonstration of post-fault OHL rating for Site #133

Next steps

The algorithm will be updated to reflect the changes captured in WPD Standard Technique: SD8A/3 (relating to the revision of overhead line ratings) which was issued in February 2020.

3 Progress against Budget

Table 3-1 summarises the details of the progress that has been made with respect to the project budget.

Table 3-1 Project progress against budget

Spend Area	Budget (£k)	Expected Spend to Date (£k)	Actual Spend to Date (£k)	Variance to Expected (£k)	Variance to expected (%)
Nortech Delivery	1049.9	733.4	714.2	-19.2	-2.6%
WPD Project Management	65.1	40.5	46.5	+6	+14.8%
WPD Network Services Costs	31.4	19.6	14.9	-4.7	-24.0%
Equipment & Hardware	39	0.0	0.0	0.0	0.0%
Contingency	118.5	0.0	0.0	0.0	0.0%
TOTAL	**1303.9**	**793.7**	**775.5**	**-18.2**	**-2.3%**

WPD Network Services Costs

This cost is underspent due to the delay in installations on the 33kV and 132kV networks, all work was due to be completed by the end of April with installations in the programme, this has now been delayed due to COVID-19 and the travel restrictions imposed by the UK government.

WPD Project Management

Overspend to date due to change over of project manager at the beginning of the project, this required additional project management days than originally anticipated.

4 Progress towards Success Criteria

Table 4-1 presents the progress the project has made towards the Success Criteria.

Table 4-1: Progress towards success criteria

Success Criteria	Progress
Power flow direction determined correctly at a minimum of 10 sites across 11kV and 33kV networks.	Criteria achieved; power flow direction determined at each site location on 11kV and 33kV networks.
Power flow direction estimated correctly at a minimum of 10 sites across 11kV and 33kV networks.	Power system models for several primary groups in the West Midlands network have been created and validated in the python package Pandapower. Time series data (TSDS) from the SCADA system has been obtained to evaluate the performance of the state estimation module in Pandapower.
Correct detection of a minimum of 5 auto-recloser operations during the project lifetime (recognising this is dependent on faults occurring).	Work is ongoing to refine the algorithm in the Smart Navigator 2.0 sensor to detect individual circuit breaker reclose operations, at present events are categorised in to permanent and momentary faults.
Direction of passage of fault current determined at a minimum of 5 sites during the project lifetime (recognising this is dependent on faults occurring).	Criteria achieved; fault passage direction determined for 36 events during the ongoing trials.
Post-fault ratings determined for at least one circuit at or above 33kV during the project lifetime.	Criteria achieved; devices at three locations on the 33kV network demonstrating post-fault rating of conductors.
Completion of trials of the five different Methods, with a report on each Method detailing the learning and updated business case for wider business adoption.	A report for the test trials has been submitted documenting progress against each Method, a report on each Method will follow later in the project.
Development of policies to facilitate the wider business adoption of the technology at the end of the project should WPD decide for BaU adoption.	This will follow later in the project.

5 Learning Outcomes

The learning across the different aspects of the project during the current reporting period is summarised below:

- On several occasions through the test trials the state of charge of the internal battery in the Smart Navigator 2.0 suffered as a result of frequent (undesirable) reporting of low line current alarms. This issue was resolved with a configuration update dispatched to devices over-the-air. The state of charge of the battery had caused the device to enter a low power mode where functionality is temporarily constrained to prevent deep discharge. Several days after the configuration update the device harvested sufficient power to re-establish full functionality, resuming data reporting every 24hrs.

- This learning resulted in an amendment to the policy for installations on 11kV circuits where phase imbalance can be prominent. The master unit consumes more battery power than satellite units as a result of power-intensive modem activities for mobile communications. It is therefore recommended that the master unit is installed on the outer of the three phases since central phases regularly suffer phase imbalance at 11kV, and consequently less power is able to be harvested by the devices.

- The data consumption of devices was reviewed with the SIM card provider for the field trial period; the values are reported for guidance in Table 5-1.

Table 5-1 – Review of SN2.0 mobile data consumption

SN2.0 reporting interval	Approximate monthly data consumption
15-minutes	30 MB
24 hours	3 MB

- The devices are small and weigh c. 1kg therefore at most sites on the 11kV and 33kV network (wood pole circuits) it is practical to install with devices with long rods.

  These devices can be installed using long stick methods instead of short stick with the support of a Mobile Elevated Work Platform (MEWP), this is advantageous when obtaining consent from landowners since there is little disturbance to domestic premises or agricultural land when using long stick methods.

6 Intellectual Property Rights

Table 6-1 presents the relevant foreground IPR that has been generated by OHL Power Pointer.

Table 6-1- Relevant Foreground IPR

IPR	Ownership	Access Location
Architecture for the OHL Power Pointer Solution	WPD / Nortech	Project Close Down Report
Policies for the installation and location of equipment	WPD	WPD Information Resources
Functional specification for the OHL monitoring device	WPD	Project Close Down Report
Functional specification for the power flow direction estimator	WPD	Project Close Down Report
Functional specification for the post-fault rating system	WPD	Project Close Down Report
Data generated through test trials	WPD	Project Close Down Report
iHost software: UI representing direction of power flow	Nortech	Nortech iHost Support
iHost software: Real-time post-fault ratings module	Nortech	Nortech iHost Support

Table 6-2 presents the relevant background IPR that has been generated by OHL Power Pointer.

Table 6-2- Relevant Background IPR

IPR	Ownership	Access Location
Trademarks, copyright and industrial processes relating to the ownership and operation of distribution network assets	WPD	WPD Information Resources
IPR generated through other innovation projects (such as FALCON, SoLa BRISTOL, FlexDGrid, ECHO etc.)	WPD	WPD's Energy Data Hub
Trademarks, copyright, industrial design and production rights relating to the Smart Navigator OHL Monitor	Nortech	Nortech Customer Support
Trademarks, copyright, industrial design and production rights relating to the iHostTM software platform	Nortech	Nortech Customer Support

7 Risk Management

Our risk management objectives are to:

- Ensure that risk management is clearly and consistently integrated into the project management activities and evidenced through the project documentation;
- Comply with WPDs risk management processes and any governance requirements as specified by Ofgem; and
- Anticipate and respond to changing project requirements.

These objectives will be achieved by:

- Defining the roles, responsibilities and reporting lines within the Project Delivery Team for risk management;
- Including risk management issues when writing reports and considering decisions;
- Maintaining a risk register;
- Communicating risks and ensuring suitable training and supervision is provided;
- Preparing mitigation action plans;
- Preparing contingency action plans; and
- Monitoring and updating of risks and the risk controls.

7.1 Current Risks

The OHL Power Pointer risk register is a live document and is updated regularly. There are currently 25 live project related risks. Mitigation action plans are identified when raising a risk and the appropriate steps then taken to ensure risks to not become issues wherever possible. In Table 7-1, we give details of our top five risks by category. For each of these risks, a mitigation action plan has also been identified and the progress of these are tracked and reported.

Table 7-1- Top five current risks (by rating)

Details of the Risk	Risk Rating	Mitigation Action Plan	Progress
Planned outages at 33kV, 66kV and 132kV (during device installation window) are rescheduled / cancelled	Severe	Strategic planning of field trials by location, avoiding areas where there is limited alternative (N-1) capacity	Installations postponed until new guidance released for non-essential operational works to continue
WPD resources unavailable	Severe	Empowering Nortech to act on WPD's behalf to gain business/stakeholder input. Detailed analysis of data obtained from field trials	Analysis using data from field trials, installations postponed until new guidance released for non-essential operational works to continue
Candidate circuits selected are not available for planned outage	Major	Outage planning for installations is one of the primary constraints in the site selection criteria	Installations postponed until new guidance released for non-essential operational works to continue
Remote communications from devices to iHost cannot be established	Major	SN2.0 contains modem with 4G capability and 2G fallback, GSM surveys carried out at each site	SIM provider requested to make 4G communications available over WPD APN

Changing of SIM cards on installed 'high voltage' SN2.0 not possible due to planned outage availability	Major	Confirmed with SIM provider that SIMs are suitable for 4G comms over WPD APN	14 sets of SN2.0s installed on circuits at risk of planned outage if manual intervention required

Table 7-2 provides a snapshot of the risk register, detailed graphically, to provide as ongoing understanding of the projects' risks.

Table 7-2 - Graphical view of Risk Register

Likelihood = Probability x Proximity						
	Certain/Imminent (21-25)	**0**	**0**	**0**	**0**	**0**
	More likely to occur than not/Likely to be near future (16-20)	**0**	**0**	**1**	**2**	**0**
	50/50 chance of occuring/Mid to short term (11-15)	**1**	**0**	**0**	**2**	**0**
	Less likely to occur/Mid to long term (6-10)	**0**	**4**	**0**	**0**	**1**
	Very unlikely to occur/Far in the future (1-5)	**0**	**2**	**5**	**2**	**5**
		1. Insignificant changes, re-planning may be required	2. Small Delay, small increased cost but absorbable	3. Delay, increased cost in excess of tolerance	4. Substantial Delay, key deliverables not met, significant increase in time/cost	5. Inability to deliver, business case/objective not viable
		Impact				

	Minor	Moderate	Major	Severe	
Legend	**12**	**7**	**4**	**2**	**No of instances**
Total	**25**				No of live risks

Figure 7-1 provides an overview of the risks by category, minor, moderate, major and severe. This information is used to understand the complete risk level of the project.

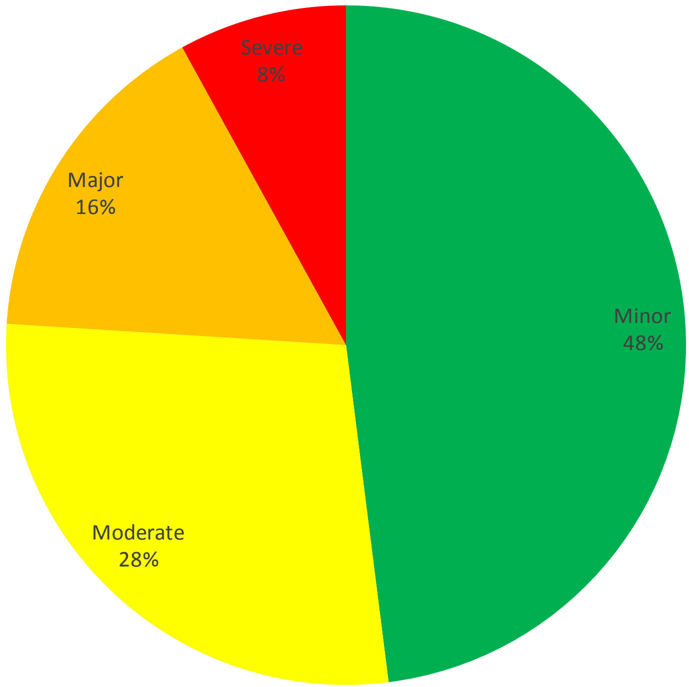

Figure 7-1 - Percentage of Risk by category

8 Consistency with Project Registration Document

The scale, cost and timeframe of the project has remained consistent with the registration document, a copy of which can be found here:
https://www.westernpower.co.uk/downloads/25963

9 Accuracy Assurance Statement

All efforts have been made to ensure that the information contained within this report is accurate. WPD confirms that this report has been produced, reviewed and approved following our quality assurance process for external documents and reports.

Glossary

Term	Definition
APN	Access Point Name
BAU	Business as usual
DG	Distributed Generation
DNO	Distribution Network Operator
FPI	Fault Passage Indicator
GB	Great Britain
GSM	Global System for Mobile Communications
HV	High Voltage
IPR	Intellectual Property Register
LCT	Low Carbon Technologies
LV	Low Voltage
MEWP	Mobile Elevated Work Platform
NIA	Network Innovation Allowance
OHL	Overhead Line
SCADA	Supervisory Control and Data Acquisition
SN2.0	Smart Navigator 2.0
TSDS	Time Series Data Store
WPD	Western Power Distribution

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