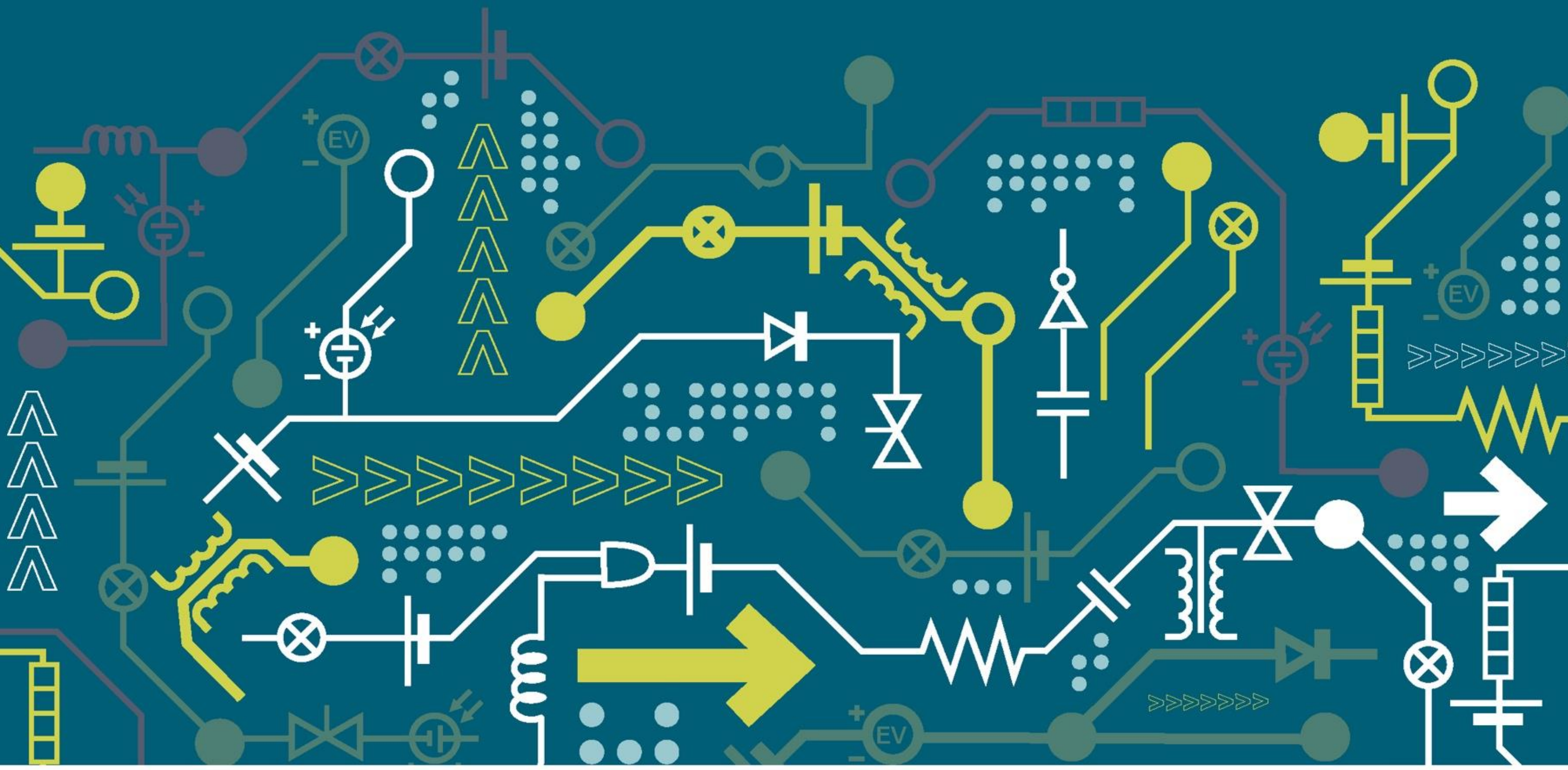
OHL (Overhead Line) Power Pointer

NIA_WPD_038

NIA Major Project Progress Report
Reporting Period:
April 2020 – September 2020



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Contents

1 Executive Summary

OHL (Overhead Line) 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.

The project budget is £1,302,413 of which £1,172,172 has come from the Network Innovation Allowance (NIA) funding.

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 we transition from a DNO (Distribution Network Operator) to a DSO (Distribution System Operator), 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 is the second progress report, covering progress from the beginning of April 2020 to the end of September 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;
- 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 communicate into Nortech's iHost monitoring platform periodically (over a live connection or once every 24hrs depending on circuit loading) to report operational data from the trial location for. Disturbances on the network are monitored by the device and alarms are generated and new events logged in iHost. 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, device health status', conductor temperature, load current magnitude, 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.

An evaluation of the time-series data recorded from the PowerOn TSDS (Time Series Data Store) system has been completed, TSDS is simply measurements or events that are tracked, monitored, and aggregated over time. With several recommendations feeding into the modelling and simulation parameters for the state estimation method. A separate report has been issued documenting the detailed findings and recommendations.

The time-series data has been stepped through in a python script to demonstrate the performance of the state estimation method on the Shrewsbury primary network, previously selected as a trial area. The impedance models were updated following the recommendations from the report on the TSDS evaluation. This produced strong simulation results, with state estimation simulations converging at frequent intervals over a 6-hour snapshot of data.

Our control team is progressing with the setup of an ICCP (Inter-Control Center Communications Protocol) link between West Midlands PowerOn and iHost to facilitate the transfer of real-time SCADA (Supervisory Control and Data Acquisition) data and enable state estimation simulations for the trial area.

Installations of 50 sets of devices on OHLs for the field trials were postponed as a result of new Covid-19 restrictions brought in by the government to control the pandemic. All non-essential works were suspended, resulting in many installations scheduled for the end of March and April being re-scheduled. Some restrictions were lifted in June and the installations for the field trials resumed. The team is working closely with network services to install the final devices for the field trials before the end of October. The field trials include installations of twenty HV Smart Navigator 2.0 sets monitoring 132kV and 66kV OHLs, which will increase depth, and compliment several months of time-series data gathered during the test trials from 33kV and 11kV networks.

WPD Telecoms and Vodafone are progressing with works on site to upgrade the 4G systems and enable visibility of the sets of Smart Navigator 2.0 devices which have been installed for the field trials. This work had been delayed due to Covid-19 measures. Since office restrictions have been relaxed, the telecoms provider has been able to undertake two lots of work on site, with a final visit pending. The 4G service is anticipated to be operational over the coming weeks.

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 for Nortech)
- George Gee (Software Developer for Nortech)

1.4 Procurement

The following table details the current status of procurement for this project.

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

Table 1-1 - Procurement Details

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)

  In 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 should we 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)
  - Conductor temperature sensing (feeding into 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.

- 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.

Installations of fifty Smart Navigator 2.0 devices across the network for the field trials were due to be completed in April 2020. Unfortunately, many of the installations that were scheduled to take place in March and April were postponed as new restrictions for Network Services teams (arising from the Covid-19 pandemic) caused all non-essential work on the network to be postponed.

Consequently, an internal update to the project milestones was requested to extend the field trial installations from 24th April 2020 to 24th October 2020. The costs to the project were absorbable and some of the analysis work was brought forward to allow the project to run in parallel without any change to budgetary requirements.

The following activities have been completed over the past six months:

- A time-series dataset from the TSDS data historian has been examined and conditioned for use with impedance models. The purpose of this exercise was to validate the sensor data, assessing magnitude and confirming the orientation of directional measurements to accurately feed into the state estimation algorithm.
- The state estimation algorithm has been successfully tested with impedance data, adapted from IPSA power system models held by the Primary System Design team. Metering points on the primary system tend to be located at primary feeders and secondary side of the power transformers. The impedance models were validated and updated where necessary, from factory acceptance test records, to reflect the true impedance of the system.
- A new release of firmware for the Smart Navigator 2.0 has been delivered by the manufacturer, Horstmann. The firmware comprised several new features, notably an option for the devices to remain continuously connected (via the mobile telecoms network) to the remote server offering real-time availability of OHL data. The firmware underwent a soak test on several devices deployed for the test trials to confirm stability. Following several iterations to enhance performance the firmware has been successfully rolled out over-the-air to all units installed for the test trials.
- Network data captured from the Smart Navigator 2.0 devices has been analysed to examine seasonal trends through the transition from spring to summer. Observations included the effects of shifting load profiles as industrial areas reduced consumption during the height of the pandemic and domestic consumption increased. In some feeders this resulted in frequent changes in direction of power flow. In some cases, small industrial sized solar arrays were considered to be supplying large sections of 11kV feeders.

Smart Navigator 2.0 installations resumed on 30th June 2020 and the team is on target to meet the extended milestone for the field trial installations on 24th October 2020.

The field trials comprise devices installed and monitoring 132kV, 66kV, 33kV and 11kV circuits. The Network services team have resumed installations since some Covid-19 restrictions have been lifted. Recent installations took place on the 132kV K-line double circuit in the South West licence area. The photographs in Figure 2-1 and Figure 2-2.

Figure 2-1 – Installations of a set of HV SN2.0 on 132kV K-line tower near to Galsworthy substation

Figure 2-2 – HV SN2.0 installation on 132kV circuit - 175mm^2 ACSR conductor

2.3 Method 1: Directional Power Flow Monitoring

The transition from a passive network to an active network requires greater visibility of the direction of power flowing through network assets. Connection of renewable distributed generation and unpredictable demand profiles of consumers has resulted in the proliferation of reverse power flows through the network. It is becoming increasingly important to monitor the direction of power flows in order to make informed decisions about switching and network operation, determine reinforcement requirements and network constraints at the planning stage, run real-time analysis to ensure curtailment requirements are accurately determined and ensure ratings of transformers are sufficient, as they are dependent on power-flow direction.

Progress within this reporting period

Smart Navigator 2.0 devices have now been installed in various locations for up to a year. The period of the last six months has presented an opportunity to observe power flows around the network through the transition from spring to summer, typically a period of lower customer demand and higher embedded solar generation output.

Concurrently, the UK (United Kingdom) was subjected to a national lock-down due to the Covid-19 pandemic. The lock-down created a dramatic shift in the consumption of electricity. Many non-essential industries were forced cease operations for a significant period, reducing large-scale demand, and many employees were required to work from home, resulting an increase in domestic electricity consumption.

Figure 2-4 presents an example of the reduction in demand during the lockdown, with data taken from one of the Smart Navigator 2.0 devices installed on the Stafford South 11kV feeder which supplies a large industrial estate. The substantial drop in demand coincides with the 23rd March 2020 when wide-ranging restrictions on freedom of movement became enforced by the government. On 10th May 2020 the government announced that those who could not work from home should return to work.
The data suggests that industrial consumer demand gradually resumed after the Spring Bank Holiday. From mid-end August there is a trough in demand, resulting from a temporary reconfiguration of the network. Towards the beginning of September there is a sharp increase in demand, this coincides with the beginning of the academic year and further encouragement from the government for the population to return to work premises.

There are several periods, particularly apparent during the lock-down, where there is reverse power flow (indicated with red power flow direction) through the circuit away from the industrial estate and other downstream consumers, back towards the primary substation at Stafford South. These periods have been assessed against two sets of Smart Navigator 2.0 devices located downstream of the industrial estate, specifically monitoring embedded wind and solar activity.

The locations of Smart Navigator 2.0 devices are given in Figure 2-3, at sites #219, #220 and #222.

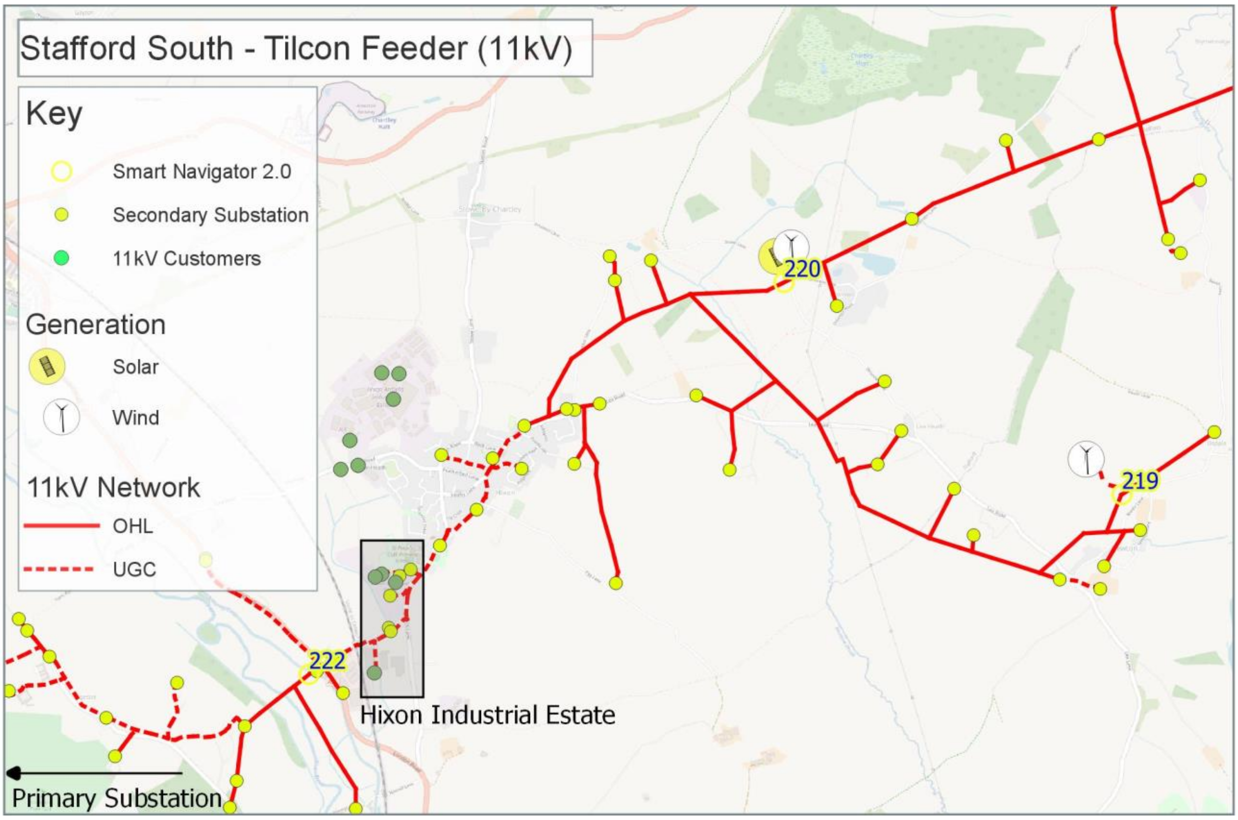

Figure 2-3 – Stafford South 11kV feeder – topology

Figure 2-4 presents the load current magnitude profile and power flow direction captured by the Smart Navigator 2.0 devices at site #222. Normally power is flowing from the substation, through the Smart Navigator 2.0 devices at site #222, towards Hixon Industrial Estate, which is indicated with the green direction. Following the enforcement of lock-down, there are multiple occasions where the reduced demand was displaced by downstream embedded generation, causing reverse power flows through the circuit at site #222, as indicated with the red direction.

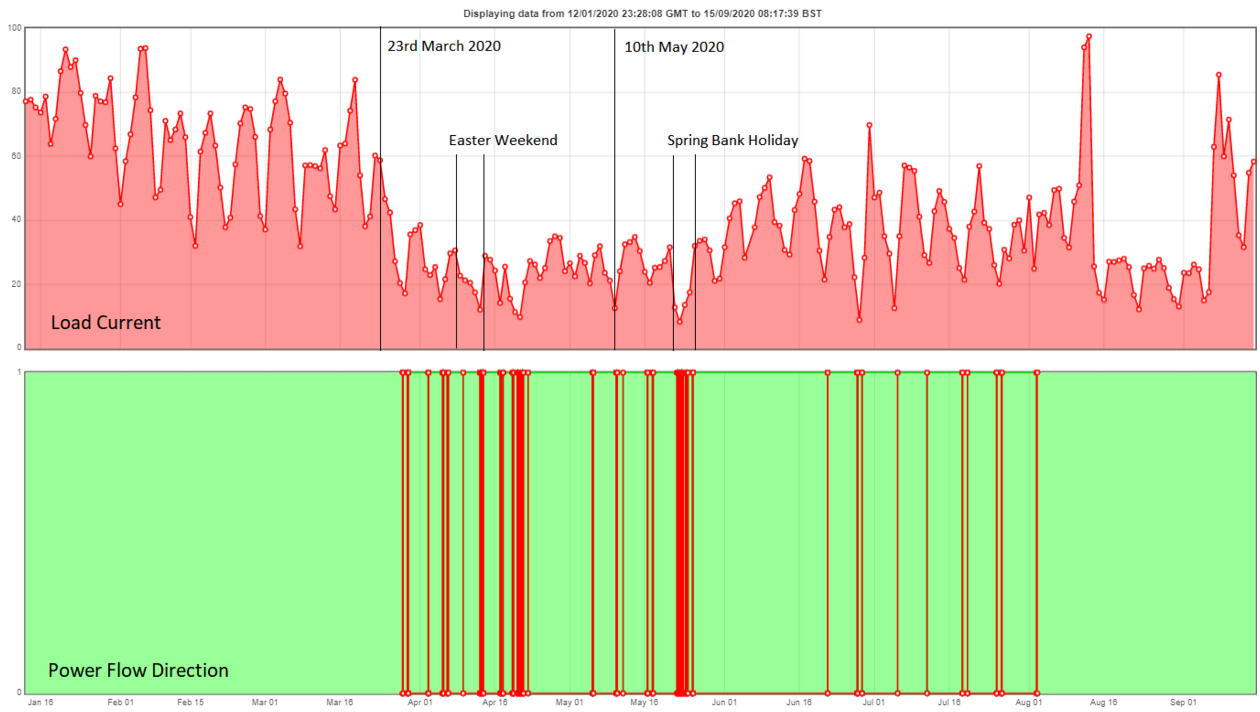

Figure 2-4 – Smart Navigator Site #222 - Stafford South 11kV feeder - load profile and power flow direction (small industrial consumers)

Figure 2-5 presents the load current magnitude profile and power flow direction captured by the Smart Navigator 2.0 devices at site #220. Frequent changes in power flow direction are visible in this figure. The green direction at this site indicates reverse power flow through the circuit towards Hixon Industrial Estate and the primary substation. There is a wind turbine and solar array connected downstream of this site.

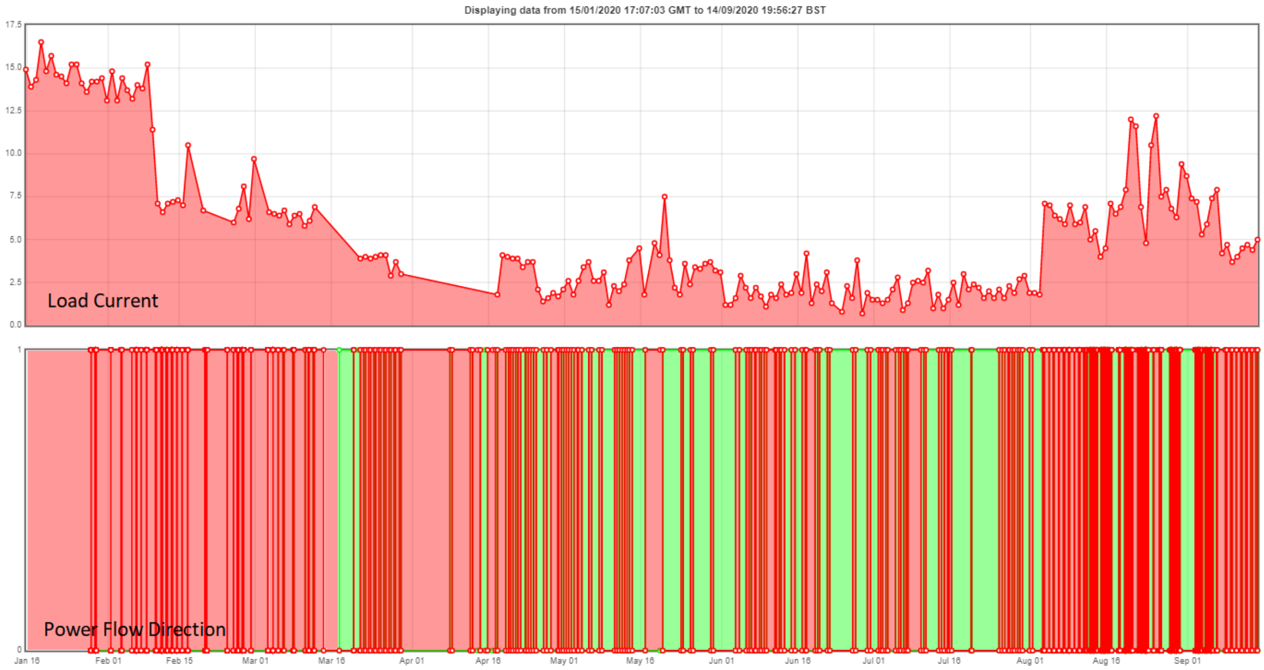

Figure 2-5 – Smart Navigator Site #220 - Stafford South 11kV feeder - load profile and power flow direction (embedded small scale wind and solar with other residential and agricultural load)

Figure 2-6 presents the load current magnitude profile and power flow direction captured by the Smart Navigator 2.0 devices at site #219. There is large wind turbine and a distribution transformer supplying a small cluster of domestic consumers downstream of site #219. The green power flow direction indicates that power is predominantly flowing towards Hixon Industrial Estate, supporting demand on the feeder.

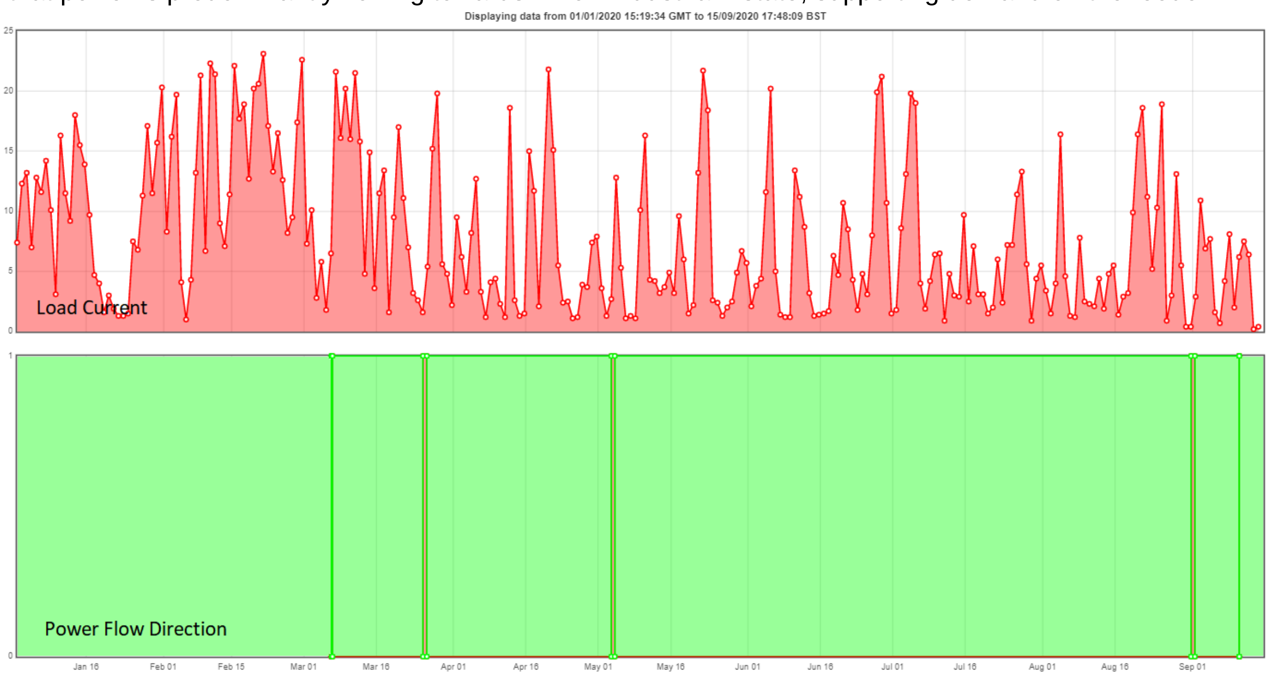

Figure 2-6 – Smart Navigator Site #219 - Stafford South 11kV feeder - load profile and power flow direction (wind turbine and single distribution transformer)

Next steps

The main trials are due to commence in October 2020, the additional units will extend the visibility of directional power flows along feeders and offer insight into wider network areas. 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 estimate' of the present state of the system using weighted linear regression techniques. State estimation is being trialling during this project for the 33kV network supplied by Shrewsbury BSP (Bulk Supply Point). Smart Navigator 2.0 devices installed on OHLs in the Shrewsbury area will be used to validate the performance of the state estimation, confirming power flow direction through circuits and current magnitudes. The trial area for the state estimation method is presented in Figure 2-7.

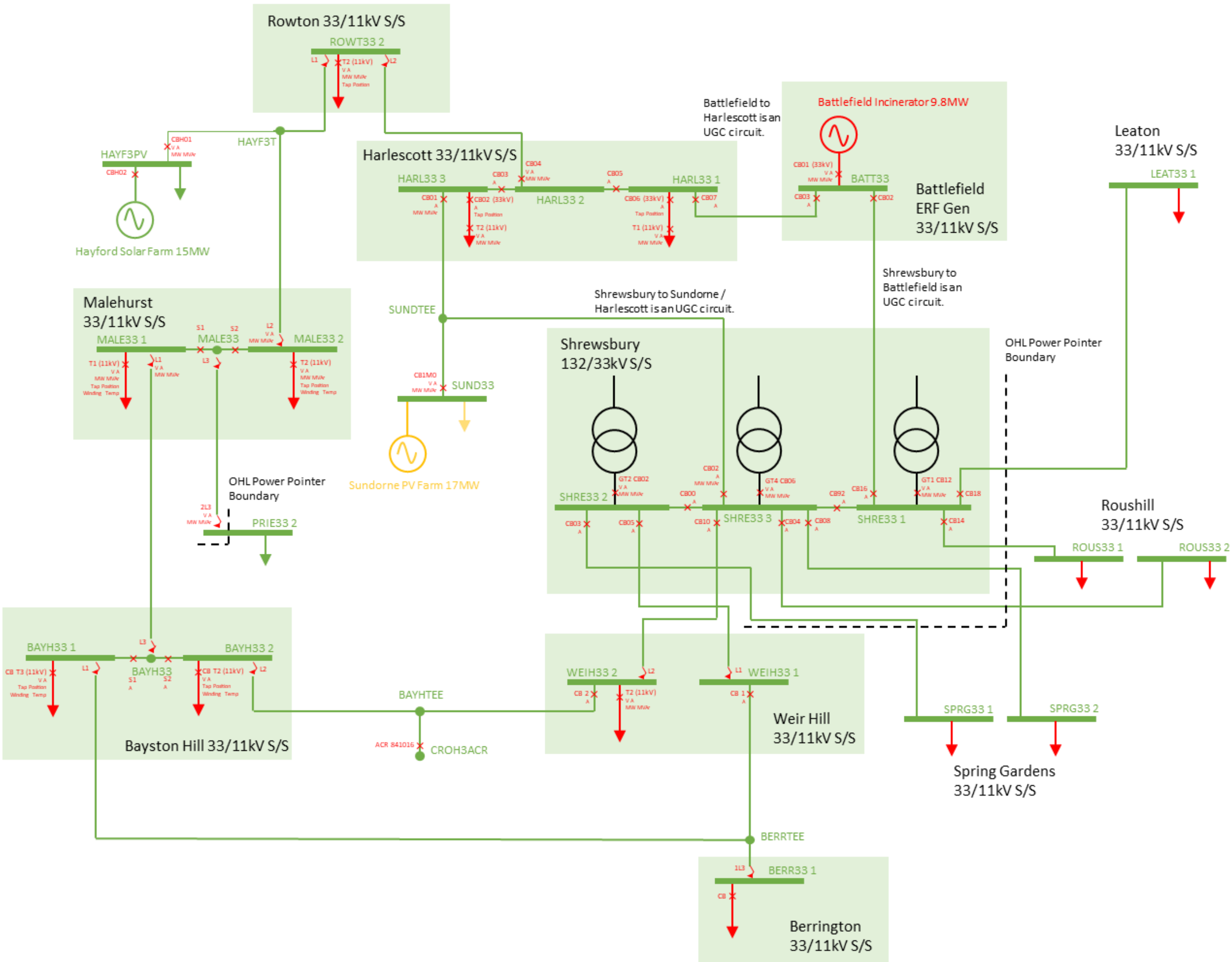

Figure 2-7 – Shrewsbury 33kV Network – trail area for the state estimation method

Progress within this reporting period

The time-series dataset captured from the TSDS during the previous period has been evaluated and offline time-series simulations have been performed on power system models of the Shrewsbury primary network. The evaluation of the data has been documented in a separate comprehensive report[1].

The study concluded that directional power flow measurements are available across approximately half of the sensors on the trial network, with measurements at other substations limited to current magnitude. The aim of the trial is to infer direction through the non-directional sensors at these locations.

The key recommendations from this study, feeding into the state estimation method, are given below:

- The orientation of the MW/MVAr measurement transducers at the following locations shall be inverted prior to state estimation analysis:
  - Shrewsbury (GT1, GT2, GT4)
  - Malehurst (Hayford / Rowton circuit)
  - Malehurst (Bayston Hill circuit)
  - Harlescott (Rowton circuit)
  - Hayford Solar (metering breaker)
- The impedance models of the power transformers at each of the primary substations in the trial area shall be updated to reflect data given in the factory acceptance test reports
- Site visits shall be undertaken to obtain copied of factory acceptance test reports and verify the tap position of transformers is accurately reflected in PowerOn
- Transducer deadbanding information was derived from the data, which shall improve the state estimate through quantification of known errors for each type of measurement
- The convention for reporting of transformer tap position to PowerOn with respect to the physical tap position at the transformer has been confirmed.

The dataset has been filtered and corrected according to the recommendations above and impedance models have been updated to reflect the network configuration as accurately as possible. State estimation simulations have been performed, feeding time-stepped data from each measurement into the impedance model to test for convergence and review the power flow results. The simulations were successful over an accelerated period of 6 hours, with new state estimates performed after each 1000 new datapoints in the dataset. The estimated power flows through branches and transformers have been tested against the recorded power flows and circuit impedances re-evaluated to ensure accurate representation of the network. The estimated power flows shall be tested against Smart Navigator 2.0 data once installations have been completed to inform on the overall accuracy of the algorithm.

The dataset was captured on the morning of 20th January 2020, over 142,000 datapoints were recorded over a 6-hour period. Network activity included large solar parks at Sundorne and Hayford steadily increasing output through the morning, exporting onto the primary system and influencing the direction of power flowing through adjacent circuits.

The prototype and demonstration of offline state estimation studies in a python script has been translated to a detailed specification for the implementation of a new software module in the iHost monitoring platform.

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[1] J417 - OHL Power Pointer - SCADA TSDS Report, Document D_003386, Issue 1.0, Dated 22/07/2020

The state estimation module in iHost will enable simulations to be performed on the impedance models with real-time data from the network, to provide visibility of directional power flows around the network.

In parallel to this exercise, WPD's Control team is progressing with the setup of the Inter-Control Center Communications Protocol (ICCP) front end processor (FEP) servers for the West Midlands PowerOn system. An additional ICCP licence is being procured to facilitate the integration of the link between PowerOn and iHost

Next steps

Planning is ongoing for the installation of additional sets of Smart Navigator 2.0 devices, which will enable the validation of estimated power flows against measured power flows in the Shrewsbury trial area. The circuit outage programme will be revisited, and the devices scheduled for installation once outages are confirmed over the forthcoming period.

The implementation of the state estimation module in iHost will continue in parallel with device installations, and the ICCP link between PowerOn and iHost is being progressed by the Control team.

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 Smart Navigator 2.0 feature set has been extended to capture the individual operations of the auto-reclosing action of circuit breakers.

The SN2.0 distinguishes between short-term (or momentary) and permanent interruptions that occur on the network, and fast-action circuit breaker operations. 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.

The new feature is being trialled on devices in the field which were deployed for the test trials.

Next steps

When auto-recloser actions occur at trial locations, the event history for the Smart Navigator 2.0 will be analysed to assess the behaviour and quantify the number of the operations. The trip count will subsequently be evaluated against the event log for the auto-recloser with assistance from the hot-glove teams on the 11kV network. This activity has been delayed as a result of restrictions in place on the network.

Once the trip count behaviour has been verified, the specification for the Smart Navigator 2.0 dashboard will be updated to capture the count of auto-recloser operations, which will 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

The Smart Navigator 2.0 feature set has been extended to provide directional fault passage indication for 2-phase and 3-phase faults.

Evaluation of the new feature ongoing, with directional fault passage indication deployed to the devices installed for the test trials.

Logic points in iHost have been implemented which enable the classification of faults, into 1-phase, 2-phase and 3-phase-to-earth faults and overcurrent faults. This presents an opportunity to display refined fault history on the Smart Navigator 2.0 dashboard. Fault events are being monitored and logic updated to accurately reflect disturbances on the network.

Next steps

The specification for the iHost dashboard shall be updated accordingly to reflect refined results for fault activity recorded by the Smart Navigator 2.0.

Analysis of directional fault activity will be documented in a detailed report as the field trials progress.

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 available capacity of circuits. This method aims to implement a post-fault OHL rating algorithm based on real-time conductor temperatures.

The post-fault rating algorithm is based on the theory presented in CIGRE Technical Brochure 601[2], 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).

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.

The new firmware release for the Smart Navigator 2.0 enables the device to operate in 'full-power' mode, where the device maintains a connection to the iHost server which enabled live reporting of OHL data. Full-power mode has been tested extensively during this reporting period. The manufacturer has optimised the firmware to allow the device to operate in full-power mode on OHLs with an average load current of c. 25 amps. The firmware was deployed to all devices

The reporting of conductor temperatures in real-time will enable the post-fault rating to be tested and evaluated at various trial sites on the network. This application of post-fault ratings is particularly beneficial for 33kV, 66kV and 132kV circuits where latent capacity in OHLs can quickly be released, where otherwise reinforcement would be necessary to relieve thermal constraints on systems.

Figure 2-8 presents data captured from a Smart Navigator 2.0 device located on the OHL circuit between Wier Hill and Bayston Hill primary substations. The device has been operating in 'full-power' mode through the summer period of 2020. The step change in the static pre-fault rating can be observed at the beginning of September. The maximum loading of this circuit has remained relatively constant throughout this period. As the maximum demand increases over the winter period the post-fault rating data will be evaluated further.

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

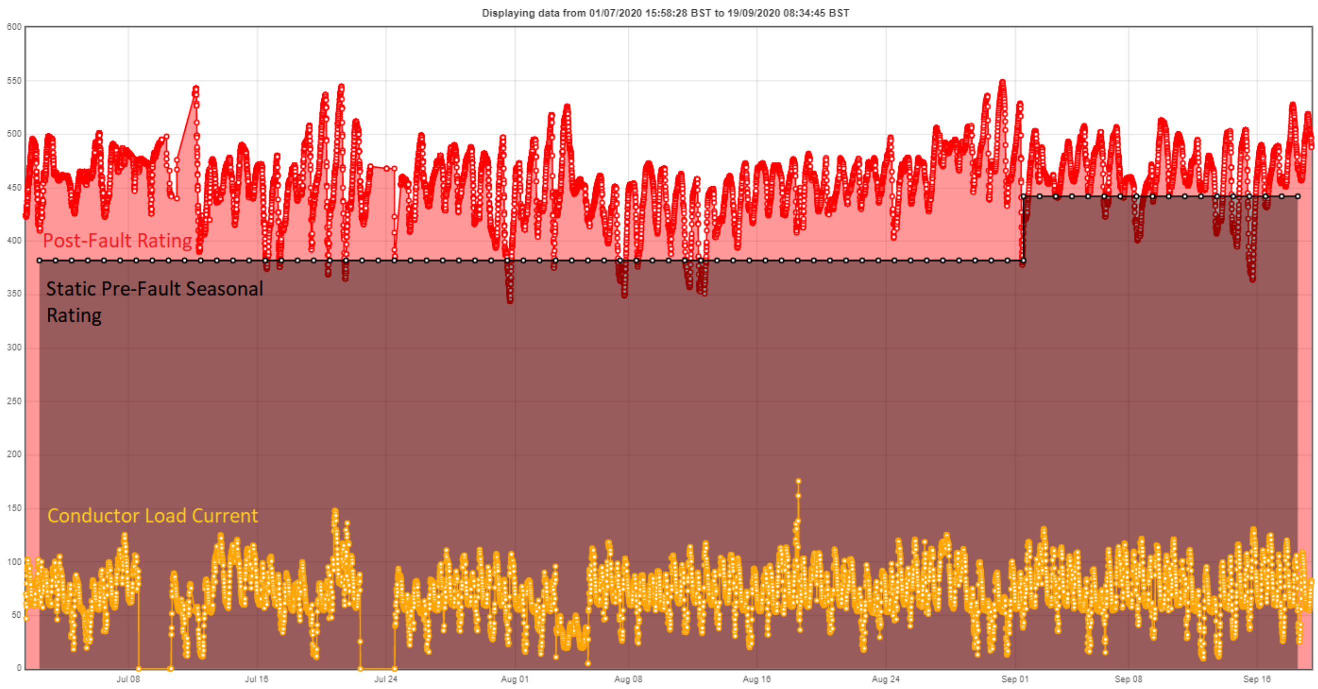

Figure 2-8 – Site #106 (Shrewsbury 33kV) post-fault rating trend (July-September 2020)

A new revision of the specification for the post-fault ratings method has been issued to the iHost team to implement the changes captured in Standard Technique: SD8A/3, which was updated to reflect the outcomes of the review of ENA ER P27[3]. The revised specification considers the changes to the definition of seasons through the calendar year and enables iHost to access a more comprehensive library of conductor data and static ratings from a wider range of standards.

Next steps

When the upgrading works for the 4G telecoms have been completed, the HV Smart Navigator 2.0 devices installed on the 66kV and 132kV networks will become visible in WPD's iHost system. This will provide further opportunities to assess the post-fault ratings method on circuits where the load can often be highly variable. Further assessment of the application of post-fault ratings will be carried out once the field trials have commenced.

[3] Energy Networks Association, Engineering Recommendation P27, Current Rating Guide for High Voltage Overhead Lines Operating in the UK Distribution System

3 Progress against 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	769.1	741.2	-27.9	-3.8%
WPD Project Management	65.1	48.0	56.0	+8.0	+14.2%
WPD Network Services Costs	31.4	19.6	15.0	-4.6	-30.6%
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**	**836.7**	**812.2**	**-24.5**	**-3.0%**

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

This cost is overspent due to increase in project management time for changeover of project managers and the delayed installations adding additional work for scheduling outages for the smart navigator installations.

4 Progress towards Success Criteria

The project has made the following progress towards the Success Criteria:

1. 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
2. Power flow direction estimated correctly at a minimum of 10 sites across 11kV and 33kV networks
   - ✓ The Shrewsbury primary group has been selected for the trial area for state estimation, the power system model has been updated using factory acceptance test data for transformers to reflect the true network impedance
   - ✓ A time-series dataset from the TSDS historian has been evaluated, findings and recommendations have been presented in a detailed report which have been used to inform the state estimation method
3. 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 evaluate the performance of the circuit breaker trip count feature in the new firmware release
4. 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 test trials
5. 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
6. 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
   - ✓ This will follow after the field trials have commenced
7. 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:

- The Smart Navigator 2.0 comprises a 2G/4G modem for mobile telecoms. For the test trials the devices were equipped with 4G roaming SIM cards from Telenor, for the field trials the devices have been equipped with SIM cards from WPD's preferred telecoms provider, Vodafone. During the assembly and test process, the devices were configured with details for WPD's Vodafone private APN (Access Point Name), to confirm communications to iHost prior to installation. It was found that whilst the SIM registered on the home network, the devices were not able to access the remote server via the private APN using 4G communications. After further diagnosis it was found that the hardware at the central communications hub required upgrading to support 4G communications over private APN. The works were scheduled, and Vodafone is progressing with the necessary hardware upgrades.

  Previously remote terminal units (RTUs) deployed to the network had been communicating over 2G/3G. The learning from this project enabled us to identify an opportunity to widen telecoms support, and other business-as-usual projects running in parallel with OHL Power Pointer will benefit from the support of 4G communications over private APN.
- We recently added the Time Series Data Store (TSDS) to its Distribution Network Management System (DNMS). The Control team provided Nortech with a 6-hour set of time series data, including Amps, Volts, MVAr, MW, MVA and tap position as well as the time of the change. Nortech evaluated the data, examining direction of power flows through the sensors, and referencing against our power measurement convention for sensors[4]. Tap positions and reactive power flows through transformers were also assessed, and common deadband thresholds were identified for each analogue measurement type.

  The key recommendations from the report are as follows:
  - Consideration should be given for the orientation of directional power flow sensors on the network to ensure alignment with the power flow convention policy
  - Tap controller / AVR (Automatic Voltage Regulator) configurations for primary transformers operating in parallel could be reviewed to prevent possible issues with circulating currents, which could be causing increased network losses
  - Where possible, power system models should reflect the true nominal voltages of primary and secondary transformer windings given in the manufacturers test reports (rather than nominal voltages of connected busbars) to prevent inaccurate LDC (Line Drop Compensation) voltage control at the secondary busbar

  The evaluation of the data captured by the TSDS and the learning obtained from the findings was key to the successful development of an offline prototype of the state estimation method.

[4] WPD Standard Technique TP6F/1 – Power Measurement Conventions (July 2007).

6 Intellectual Property Rights

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

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 6-1 - Relevant Foreground IPR

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

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

Table 6-2 - Relevant Background IPR

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.

Details of the Risk	Risk Rating	Mitigation Action Plan	Progress
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
Device does not comply with regulations	Major	Product designed to international standards; standards identified before technical specification stage	Functional specification and FAT approved by WPD
Planned outages at 33kV, 66kV and 132kV (during device installation window) are rescheduled / cancelled	Major	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	Major	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

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

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

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**	**0**	**0**	**0**
	50/50 chance of occuring/ Mid to short term (11-15)	**1**	**0**	**1**	**3**	**0**
	Less likely to occur/Mid to long term (6-10)	**0**	**4**	**0**	**1**	**1**
	Very unlikely to occur/Far in the future (1-5)	**0**	**2**	**4**	**2**	**4**
		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	**11**	**6**	**6**	**0**	**No of instances**
Total	**23**				No of live risks

Table 7-2 - Graphical view of Risk Register

Table 7-3 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.

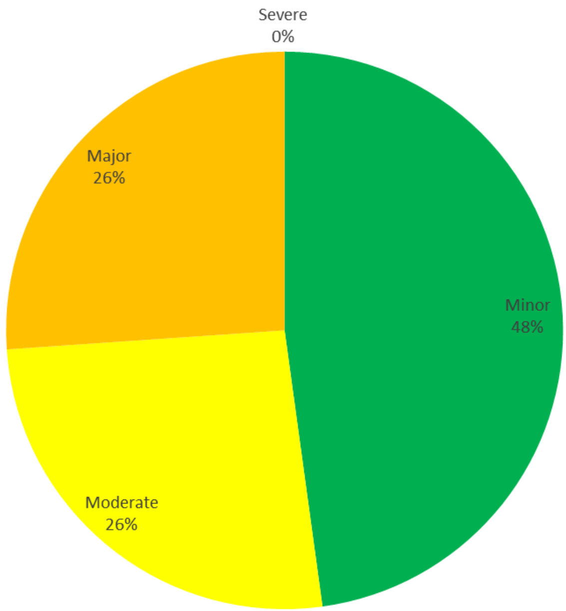

Table 7-3 - Percentage of Risk by category

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

This report has been prepared by the OHLPP Project Manager (Ben Brewin) and by WPD Project Manager (Steven Pinkerton-Clark), reviewed by WPD Innovation Engineer (Faithful Chanda) and approved by the WPD Innovation Team Manager (Yiango Mavrocostanti).

All efforts have been made to ensure that the information contained within this report is accurate. We confirm 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
DNMS	Distribution Network Management System
DNO	Distribution Network Operator
FEP	Front End Processor
FPI	Fault Passage Indicator
GB	Great Britain
GSM	Global System for Mobile Communications
HV	High Voltage
ICCP	Inter-Control Centre Communications Protocol
IPR	Intellectual Property Register
LCT	Low Carbon Technologies
LV	Low Voltage
NIA	Network Innovation Allowance
OHL	Overhead Line
SN2.0	Smart Navigator 2.0
TSDS	Time Series Data Store
WPD	Western Power Distribution

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