Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

Network Licensees must publish the required Project Progress information on the Smarter Networks Portal by 31st July 2014 and each year thereafter. The Network Licensee(s) must publish Project Progress information for each NIA Project that has developed new learning in the preceding relevant year.

NIA Project Annual Progress Report Document

Date of Submission

Jun 2022

Project Reference

NIA_WPD_038

Project Progress

Project Title

OHL (Overhead Line) Power Pointer

Project Reference

NIA_WPD_038

Funding Licensee(s)

WPD - Western Power Distribution (East Midlands) Plc

Project Start Date

December 2018

Project Duration

3 years and 6 months

Nominated Project Contact(s)

Steve Pinkerton-Clark

Scope

The project will be delivered in over the course of three years, in three phases, as summarised below.

Phase 1: Design and Build (December 2018 – March 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 (August 2019 – February 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 (December 2018 – 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.

Objectives

1. Create policies for equipment installation and location;

2. Carry out assessments of the accuracy and consistency of determining power flow directions within WPD's distribution network;

3. Provide recommendations on the number and location of devices needed for full visibility of power flow direction;

4. Quantify the savings gained by using the Smart Navigator to detect and communicate auto-recloser operations (rather than using visual inspections of AR equipment);

5. Quantify the savings made to Customers Minutes Lost (CMLs) through the use of OHL directional FPIs;

6. Provide the control room with visibility of overhead line real-time post-fault ratings;

Success Criteria

1. Power flow direction determined correctly at a minimum of 10 sites across 11kV and 33kV networks;

2. Power flow direction estimated correctly at a minimum of 10 sites across 11kV and 33kV networks;

3. Correct detection of a minimum of 5 auto-recloser operations during the project lifetime (recognising this is dependent on faults occurring);

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);

5. Post-fault ratings determined for at least one circuit at or above 33kV during the project lifetime

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; and

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.

Performance Compared to the Original Project Aims, Objectives and Success Criteria

Performance against project aims and objectives

Create policies for equipment installation and location

Complete – Policies have been drafted and have undergone our internal review process. Policies awaiting to be approved and adopted into the wider business.

Carry out assessments of the accuracy and consistency of determining power flow directions within our distribution network

Complete – we have proven that we can detect power flow direction change across our trial sites. A final report detailing the results of directional power flow detection has been published.

The data has been validated against SCADA records from local substation transducer equipment.

Provide recommendations on the number and location of devices needed for full visibility of power flow direction

Complete – this objective is detailed in the Method 1 report and details the number of SN2.0 required to achieve for full visibility.

Quantify the savings gained by using the Smart Navigator to detect and communicate auto-reclose operations (rather than using visual inspections of AR equipment

Complete – this objective will be detailed in the closedown report but the trials have completed and we have successfully identified AR operations through SN2.0 monitoring.

Quantify the savings made to Customers Minutes Lost (CMLs) through the use of OHL directional FPIs

Ongoing – This exercise will be based upon evidence demonstrated in OHLPP case studies and will be discussed in the close down report.

Provide the control room with visibility of overhead line real-time post-fault ratings

Complete – The capability to calculate post fault ratings was developed. In addition we learnt that post fault ratings are most useful when applied within ANM schemes.

Performance against success criteria

Power flow direction determined correctly at a minimum of 10 sites across 11kV and 33kV networks

Complete - Power flow direction determined at each site location on 11kV and 33kV networks, we have also determined power flow direction changes near 132kV connected solar farms

Power flow direction estimated correctly at a minimum of 10 sites across 11kV and 33kV networks:

Complete - The Power Network Analyser feature in host has successfully demonstrated state estimation using a dataset obtained from Power on TSDS for the Shrewsbury 33kV network.

Correct detection of a minimum of 5 auto-reclose operations during the project lifetime (recognising this is dependent on faults occurring)
Complete - correct detection of more than 5 auto-reclose operations during the project lifetime.

Direction of passage of fault current determined at a minimum of 5 sites during the project lifetime (recognising this is dependent on faults occurring):

Complete - Fault passage direction determined for 36 events during the test trials. Further fault activity will be observed over the remaining duration of the main trials

Post-fault ratings determined for at least one circuit at or above 33kV during the project lifetime

Complete - devices at three test trial locations on the 33kV network demonstrating post-fault rating of conductors. The method was

being tested on 33kV, 66kV and 132kV circuits at the main trail locations.

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

Complete – final reports on each of the methods have been delivered and a business case for the wider deployment of the solution across 11kV circuits has been prepared.

Development of policies to facilitate the wider business adoption of the technology at the end of the project should WPD decide for Bau adoption

Complete – policies (Standard Techniques) for the Installation of the solution on OHLs, Control & Operation and Maintenance & FAQ have been prepared. The existing policy for use of live-line techniques for installation of monitoring devices on 11kV and 33kV networks has been updated.

Required Modifications to the Planned Approach During the Course of the Project

A change request was approved in July 2021 to extend the projects main trial period by six months. The extra six months was due to the COVID-19 pandemic as some installations were cancelled and re-scheduled, these were installed after restrictions were lifted and following government guidelines.

In addition, we learnt that it was difficult to book 132 kV outages solely for installing smart navigators. Instead, the project plan had to be
modified to nest the installation into the next planned shutdowns. For this reason, the project team selected suitable sites that had existing pre-approved shutdowns.

Lessons Learnt for Future Projects

The project has generated the following learning:

Installations
Installations of the SN2 devices was quick and efficient using live line techniques following company policies and procedures, however, installations on 33kV to 132kV was increasingly difficult due to the requirement to have a full outage before the units could be fitted.

• 11kV – these were very easy to install using long stick techniques and we were able to install between 5 and 10 sets per day.
33kV – this proved the most difficult to install due to the requirement to isolate and earth each location where a set of navigators were to be installed. Discussions with our policy engineers and our safety department enabled a change in live line policy to extend the live line techniques up to 33kV for installing monitoring devices; this came into effect in January 2021.
• 132kV – this application was most difficult because these devices cannot be installed using live line techniques and it was hard to book outages that were not in the year-ahead outage plan. In the future installation of these units on 132 kV systems should be included as part of planned works.

After monitoring the installations of the navigators, it became increasingly clear that the in general, the middle phase on an overhead line had the least amount of current flowing through it at 11kV. This had the potential to cause problems if the master unit within the set was inadvertently placed on a phase that would not have enough current to sustain the self-powering aspect of the SN2's1. The project team overcame this be ensuring that the master unit was always placed on one of the outer phases to help ensure successful self-powering.

Monitoring & Trials

The real-time conductor-temperature based post-fault rating method has been trialled. Preliminary learning suggests this methodology does result in an improvement in capacity headroom, but questions need to be resolved as to how this post-fault headroom is utilised. The most likely use case for it is by combining it with active network management rather than manual application by control engineers.

Savings made to Customers Minutes Lost (CMLs) with OHL directional FPIs has been explored. In one particular case study, use of information from a set of SN2 enabled faster restoration of customers and demonstrated a strong potential to reduce the dependency on helicopter line patrols to help find damage.

Cyber Security and Control Systems
Our cyber security team has carried out penetration testing of the Smart Navigator 2.0 sensors to assess the security features against unauthorised intrusion into the devices. The testing has been successfully completed and passed. It was determined that a considerable effort has been made to protect the units from cyber-attacks. All of our attempts at compromise were unsuccessful and no access was able to be gained to the systems once a PIN had been put in place. As such, it is our recommendation that PIN numbers be set on each of the Smart Navigator units to avoid the possibility of tamper by non-WPD personnel.

Note: The following sections are only required for those projects which have been completed since 1st April 2013, or since the previous Project Progress information was reported.

The Outcomes of the Project

The project is currently in the final phase (Analysis and Reporting). The following key outputs and milestones have been completed since the project was registered:

The functional requirements specification has been prepared for the OHL sensor, documenting 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
· The OHL Power Pointer solution has been developed, the Smart Navigator 2.0 was selected for monitoring OHLs.

Factory acceptance testing of the Smart Navigator 2.0 was carried out successfully at the manufacturer’s facilities and witnessed by our Innovation Team.

The trial location methodology was established in preparation for the deployment of the Smart Navigator 2.0 solution for field trials.

Test trials were completed, where 50 sets of Smart Navigator 2.0 were installed at trial locations for monitoring of 11kV and 33kV OHL networks in the West Midlands licence area. The test trials produced a large dataset of operational OHL data which has been recorded in Nortech’s iHost monitoring platform.

Penetration testing report by WPD Cyber Security of the SN2.0 devices, these devices passed the testing carried out with minor improvements suggested and will be implemented.

Report on Method 1: Directional Power Flow Detection

This project has delivered a solution for the real-time monitoring of power flow direction through overhead line conductors without the requirement for a grounded voltage reference. The DSO can obtain significant operational benefit through the provision of an easy-to install clip-on sensor which can provide power flow, fault flow and conductor temperature visibility which can be installed on OHLs without

Disruption to electricity services.

Report on Method 2: Directional Power Flow State Estimation

This project has delivered a solution for the real-time directional power flow state estimation of the distribution network. The method utilises impedance models and available system measurements to estimate voltage angles and magnitudes at each bulbar in the network.

The solution has been tested using a live network topology and data from the SCADA system to evaluate the accuracy and effectiveness in networks with limited visibility of directional power flows over the SCADA system.

Report on Method 3: Detection of Auto-reclose Operations

The project has delivered a solution for the real-time capture of fault activity and recording of circuit breaker trip operations. The method has investigated the operation of several different types of auto-reclosing circuit breaker equipment in use across the West Midlands distribution network for the protection of HV feeders at primary substations and at key intervals along HV feeders.

Report on Method 4: Directional Fault Detection

The project has delivered a solution for the detection and indication of directional fault currents through OHL circuits. The method has investigated the capture of overcurrent and earth faults, transient and permanent faults on 11kV, and 33kV and 66kV OHL circuits across the West Midlands licence area.

Report on Method 5: Conductor Temperature Monitoring

The project has demonstrated the capability of real time conductor temperature monitoring. The project has monitored the effects of ambient temperature and load on the temperature of the conductors across the various seasons. This data could be used to implement enhanced ratings of OHL conductors using real time monitoring.

Innovation Team.

Data Access

To request access to project data, please visit: www.westernpower.co.uk/Innovation/Contact-us-and-more/Project-Data.aspx

Foreground IPR

Architecture for the OHL Power Pointer Solution WPD / Nortech
Policies for the installation and location of equipment WPD
Functional specification for the OHL monitoring device WPD
Functional specification for the power flow direction estimator WPD
Functional specification for the post-fault rating system WPD
Data generated through test trials WPD
iHost software: UI representing direction of power flow Nortech
iHost software: Real-time post-fault ratings module Nortech
Penetration Testing Report on SN2.0 devices WPD
Report on Method 1: Directional Power Flow Detection WPD / Nortech
Report on Method 2: Directional Power Flow State Estimation WPD / Nortech
Report on Method 3: Detection of Auto-recloser Operations WPD / Nortech
Report on Method 4: Directional Fault Detection WPD / Nortech
Report on Method 5: Conductor Temperature Monitoring WPD / Nortech