WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS

PRIMARY NETWORKS POWER QUALITY ANALYSIS

WPD_NIA_028

NIA MAJOR PROJECT PROGRESS REPORT

REPORTING PERIOD:

OCT 2018 – MARCH 2019

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Contents

1 Executive Summary

Primary Networks Power Quality Analysis (PNPQA) is funded through Ofgem's Network Innovation Allowance (NIA). PNPQA was registered in March 2018 and will be complete by February 2021.

PNPQA aims to reduce uncertainties around the power quality (PQ) within Primary Networks and facilitate increased integration levels of low carbon technologies (LCTs). This will be achieved through implementing a monitoring and analysis system for assessing the PQ and harmonic content of waveforms in Primary Networks, verifying the accuracy of the Primary Network equipment used for PQ monitoring, and using modelling to predict the future PQ impacts of increased integration of LCTs.

This report details progress of the project during the period October 2018 to March 2019.

1.1 Business Case

Over recent years there has been a sharp increase in the amount of LCTs connected to the electricity network as part of the transition to a low carbon economy. Significantly more LCTs will need to connect in order for the UK to reach its decarbonisation goals. Connections of LCT generators are set to continue at a pace; for instance, since PNPQA was registered National Grid revised up their estimate of LCT generation capacity by 2030 from 83 GW to 100 GW[1], which is over double the present capacity. Additionally, the UK Government's Clean Growth Strategy[2] targets electrification of transport and heating, which indicates there will be a significant increase in LCT demand connections.

LCTs are often connected to the network using power electronic interfaces that have different characteristics to the types of generators and demands that connected in the past. The impact of LCTs on power quality (such as harmonics, flicker, voltage sags and swells, and voltage unbalance) within primary networks is uncertain, particularly the future impacts of increased LCT integration.

In order to facilitate LCT connections, WPD is required to publish PQ information; however, current business practices would make this labour- and cost- intensive to achieve fully. At present PQ monitoring is limited in both space and time, typically with a single site being monitored in an area for a week per year, or less. As a result, worst-case operating conditions may not be captured, and there is little visibility of PQ away from LCT points of connection. Data retrieval requires site visits and analysis of PQ data is not automated, making the process labour-intensive. In addition, there is uncertainty that the network equipment used for PQ monitoring is providing an accurate picture of PQ within the networks. PNPQA aims to overcome these shortcomings and provide widespread visibility of PQ within Primary Networks in a much more labour- and cost-efficient way than simply scaling up the present approach.

[1] National Grid, Future Energy Scenarios (2018 and 2017): http://fes.nationalgrid.com/
[2] https://www.gov.uk/government/publications/clean-growth-strategy

1.2 Project Progress

This is the second progress report, covering progress from the start of October 2018 to the end of March 2019.

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

1. Design – this is the first phase and is currently drawing to a close, which includes testing the harmonic performance of voltage transformers (VTs), selection of trial areas and sites, specifying PQ monitor interfaces and PQ analysis software, and PQ monitor connection design;
2. Build – this the current phase, which includes developing interfaces to enable remote communications from PQ monitors, purchasing and installing PQ monitors, and developing software to automate the retrieval and analysis of PQ monitor data;
3. Trial – this is the next phase of the project and combines a widescale trial of communicating power quality monitors with software to automate the collection and analysis of PQ data, along with modelling to understand the future impact of increased LCTs on Primary Networks; and
4. Report – this is the final phase of the project, and includes dissemination events and producing the close down report.

Two trial areas have been confirmed for the widescale trial of communicating PQ monitors, following site surveys and detailed analysis. The 33 kV network fed from Meaford C Bulk Supply Point (BSP), located between Stoke-on-Trent, Stafford, and Market Drayton, has a low penetration of LCTs, and will be used as the base-case low LCT trial area. The network fed by Ryeford BSP, centred on Stroud, has a high penetration of LCTs so will be used as the high LCT trial area.

Three different PQ monitors have been bench tested by Nortech, to understand what interfaces they offer; based on these tests, Nortech is developing those interfaces in to the firmware of a communications hub that will enable remote communication of PQ data. PQ monitors have been ordered and delivered in preparation for the trials. Installation locations and concept designs have been created for the PQ monitor trial, and discussions are continuing to arrange for WPD resources to perform PQ monitor installation work.

High-level requirements for software to automate the retrieval and analysis of PQ data have been set, and detailed functional specifications and initial development work has progressed for the first main features of the software.

A review of power system analysis software has determined which software should be used for the project's PQ studies.

Testing the harmonic performance of VTs has been completed at The University of Manchester, with several 11 kV and 33 kV VTs being sourced used from within WPD and new from manufacturers for testing. A technical paper summarising the results of the VT testing has been submitted for the CIRED 2019 conference.

1.3 Project Delivery Structure

1.3.1 Project Review Group

The PNPQA Project Review Group meets on a bi-annual 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: Jonathan Berry (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)
- James King (Project Manager for Nortech)
- Sid Hoda (Software Development Manager)
- Simon Hodgson (Technical Manager)

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, PQ monitor interface hardware, software development	All	March 2018 – February 2021
The University of Manchester	VT harmonic performance testing	VT testing	June 2018 – April 2019
(undisclosed)	33 kV 1-phase VT	VT testing	Delivered October 2018
(undisclosed)	33 kV 1-phase VT	VT testing	Delivered October 2018
7com Ltd	Demo PQ monitor	PQ monitor trials	Delivered July 2018
IMH Technologies Ltd	Demo PQ monitor	PQ monitor trials	Delivered July 2018
Siemens PLC	Demo PQ monitor	PQ monitor trials	Delivered October 2018
7com Ltd	PQ monitors for trials	PQ monitor trials	Delivered February

Provider	Services/goods	Area of project applicable to	Anticipated Delivery Dates
	(a-eberle PQI-DA smart)		2019
IMH Technologies Ltd	PQ monitors for trials (PSL PQube3)	PQ monitor trials	Delivered February 2019
Siemens PLC	PQ monitors for trials (Siemens SICAM Q200)	PQ monitor trials	Delivered February 2019

Table 1-1: Procurement Details

1.5 Project Risks

A proactive role in ensuring effective risk management for PNPQA 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 PNPQA 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.

Due to the early stage of the project no dissemination events have been held. A paper has been submitted for the CIRED conference 2019, which will be used to disseminate the findings from the VT harmonic performance testing (please refer to section 2.3.2 for details).

2 Project Manager's Report

2.1 Project Background

PNPQA is split in to four phases:

1. Design – this first phase of the project is drawing to a close, and includes testing the harmonic performance of VTs, selection of trial areas and sites, specifying PQ monitor interfaces and PQ analysis software;
2. Build – this is the current phase, which includes developing interfaces to enable remote communications from PQ monitors, purchasing and installing PQ monitors, developing software to automate the retrieval and analysis of PQ monitor data, and building power system models for future-looking PQ studies;
3. Trial – this is the next phase, which combines a widescale trial of communicating power quality monitors with software to automate the collection and analysis of PQ data, along with modelling to understand the future impact of increased LCTs on Primary Networks; and
4. Report – this is the final phase of the project, and includes dissemination events, creation of policies for business-as-usual adoption, and producing the close down report.

2.2 Project Progress

The project is currently in the second phase (Build), with some final activities running concurrently from the first phase (Design). The following progress made:

- Testing the harmonic performance of VTs has been completed at The University of Manchester, with several 11 kV and 33 kV VTs being sourced used from within WPD and new from manufacturers for testing;
- Two networks areas have been selected for the main trials of communicating power quality monitors (Ryeford and Meaford C), after site surveys were completed;
- Three different PQ monitors have been bench tested by Nortech, to understand what interfaces they offer; based on these tests, Nortech is developing those interfaces in to the firmware of a communications hub that will enable remote communication of PQ data;
- Installation locations and concept designs have been created for the PQ monitor trial, and discussions are continuing to arrange for WPD resources to perform PQ monitor installation work;
- High-level requirements for software to automate the retrieval and analysis of PQ data have been set, and detailed functional specifications and initial development work has progressed for the first main features of the software; and
- A review of power system analysis software has determined which software should be used for the project's PQ studies.

More detail of the progress within each of these activity areas for phase 1 is provided in the subsections within section 2.3 below, and for phase 2 within section 2.4. Phases 3 and 4 have not yet started so no progress is reported for them. Next steps for within the next reporting period are described in section 2.5.

2.3 Phase 1: Design

The Design phase includes several activities that run from the start of the project up to the initial part of the subsequent Build phase. Most of the Design phase activities were completed during the present reporting period, and progress within each of these activities is described in the following subsections including next steps.

2.3.1 Monitoring Pilot

A widescale trial of communicating PQ monitors is a major part of PNPQA and is due to start in mid-2019. In order to gain some early learning with a communicating power quality monitor, a pilot trial of with a single monitor was completed.

Progress within this reporting period

The Outram PM7000 PQ monitor installed at Meaford C substation in June 2018 has remained in place and has data has continued to be collected remotely in to Nortech's iHost web-based control and monitoring platform via a Nortech Envoy communications hub.

No further analysis of the collected data has taken place. Please refer to the previous report for analysis of data collected during 2018.

2.3.2 VT Testing

For PQ monitoring, it may only be practical to use existing VTs to obtain voltage measurements; however, the harmonic performance requirements of these VTs may not have been specified or guaranteed, and little data is available on their performance. Therefore, to gain a better understanding of VT performance and their influence on harmonic measurements, several VTs, representative of those used by WPD, have been laboratory tested as part of PNPQA.

Progress within this reporting period

The University of Manchester (UoM) has been contracted to perform the laboratory testing, based on similar previous work there by a PhD student.

In the previous reporting period, examples of used VTs were sourced from within WPD for the testing and the UoM developed the test circuit and procedure and performed some initial tests. In the present reporting period, additional new VTs were sourced, all VTs were tested, and the UoM checked the calibration of the test equipment.

Four VTs have been tested:

1. An 11 kV 3-phase cast-resin VT, which had been previously used within switchgear (an 11 kV metering unit);
2. A 33 kV 3-phase oil-filled VT, which had been previously used outdoors at a substation;
3. A 33 kV 1-phase cast-resin VT, which was sourced new from a manufacturer; and
4. A second 33 kV 1-phase cast-resin VT, which was sourced new from a different manufacturer.

A fifth VT had been sourced – a used 11 kV old-filled VT – but could not be tested due to an insulation fault.

Figure 2-1 shows the frequency response up to the 50th harmonic (2500 Hz) of each phase of the 11 kV 3-phase VT from the laboratory testing at the UoM, with both the normalised ratio and the phase shift shown for each phase. The normalised ratio quantifies the relationship between the actual output of the VT and the expected output based on the nameplate ratio. A normalised ratio of 1.0 indicates the magnitude of the output is as expected; however, values less than 1.0 – as shown in the figure for higher frequencies – indicate the output is lower than expected. The lowest normalised ratio shown in the figure is 0.34 for phase L2 at 2500 Hz, which is a third of the expected value. The phase shift is measured between the input of the VT and the output.

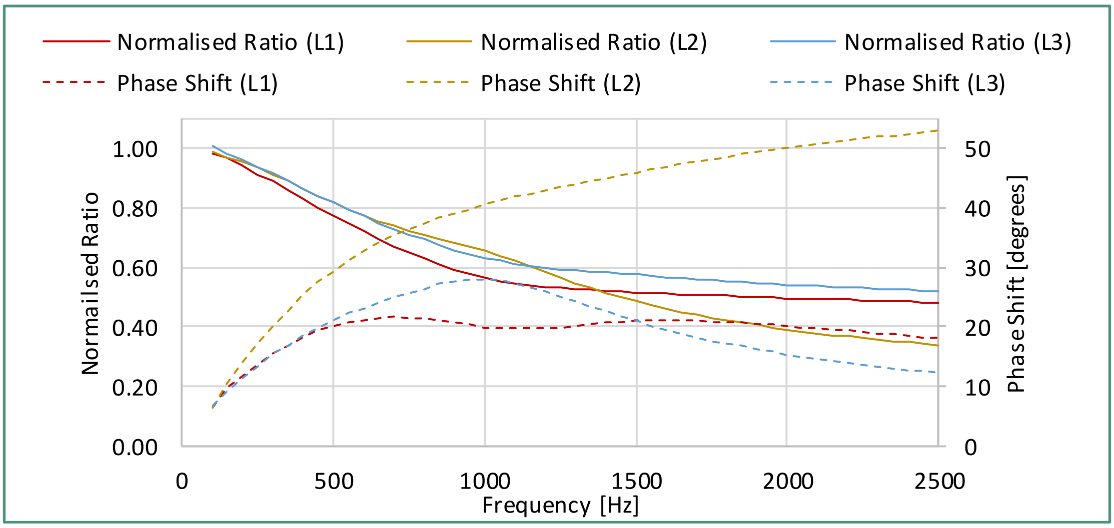

Figure 2-1 – Frequency response of 11 kV 3-phase VT

Figure 2-2 shows the frequency response of the 33 kV 3-phase VT. It is similar to the response of the 11 kV VT, in that the normalised ratio reduces as frequency increases, meaning the magnitude of higher frequency harmonics are attenuated by the VT. A similar trend was observed for both 33 kV 1-phase VTs, as shown in Figure 2-3.

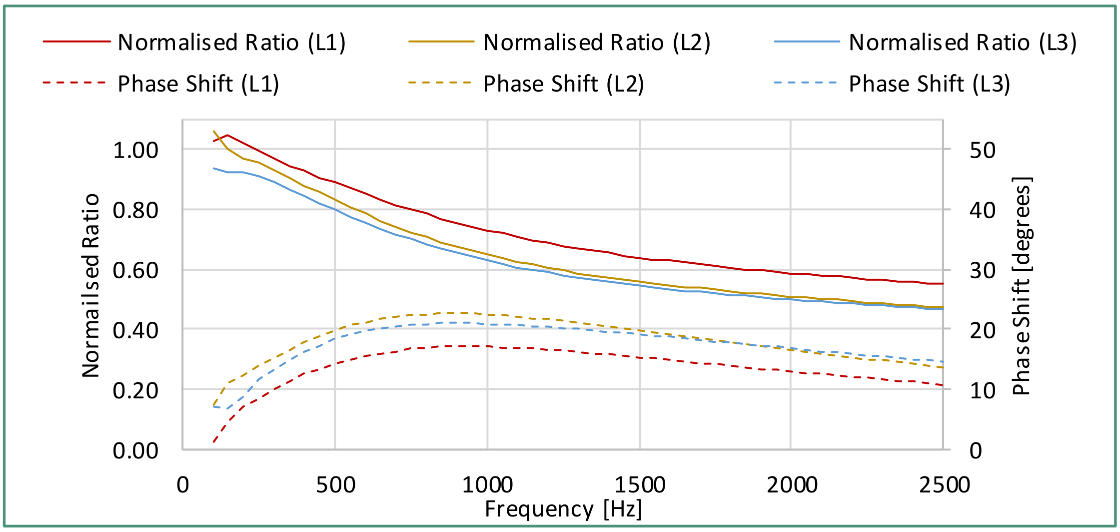

Figure 2-2 – Frequency response of 33 kV 3-phase VT

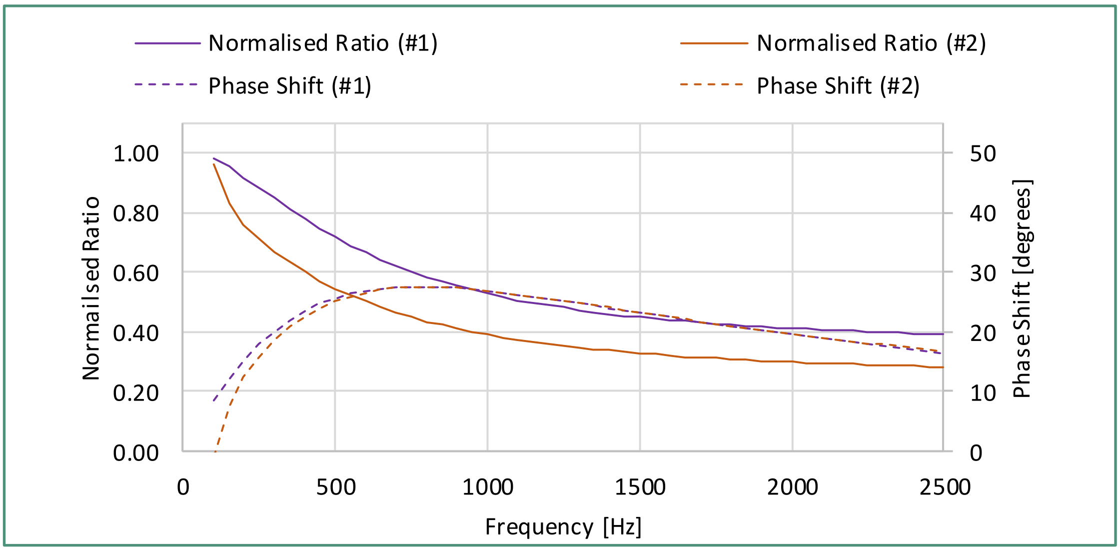

Figure 2-3 – Frequency response of 33 kV 1-phase VTs

The results from testing the four VTs are consistent with the results of the initial testing that was presented in the report for the previous reporting period:

- The normalised output/input ratios at the nominal frequency (50 Hz) closely match what would be expected based on the transformer nameplate ratios;
- The normalised ratios decrease (attenuate) as frequency increases; in other words, the higher the frequency, the lower the signal is on the secondary side of the VT. At the 50th harmonic the output signal magnitude can be 55% or less than what would be expected based on the transformer nameplate ratio alone; and
- For the 3-phase VTs, there are differences in the normalised ratios and phase shifts for each of the 3 phases. This is due to the construction of a 3-phase transformer, which results in asymmetry in the magnetic flux distribution between the phases and thus leads to voltage differences.

The results of the VT testing suggest that the VTs in use by WPD – and which are used by other DNOs – do distort harmonic voltage signals, in that output signals at higher frequencies are attenuated. However, this does not mean the VTs are unsuitable for PQ measurements, so long as the attenuation of the output signal at higher frequencies is accounted for, either through careful consideration the harmonic limits the measurements are checked against, or by adjusting the results of measurements obtained from the VTs.

A technical paper on the VT testing has been prepared for the CIRED 2019 conference.

2.3.3 Trial Area & Site Selection

PNPQA includes a widescale trial of communicating PQ monitors in two areas of Primary Network that will provide invaluable detailed and long-term PQ data to understand the current and potential future impacts of increased levels of LCTs in distribution networks. Carefully selecting the two trial areas and the sites within them for the trial has been the main related activity during this phase of the project.

Progress within this reporting period

In the previous reporting period, selection criteria were developed and applied to identify two candidate areas for the PQ monitor trials, differentiated by their level of LCT penetration:

- "High" LCT: the network fed from Ryeford BSP, centred around Stroud, Gloucestershire, and extending to the Severn in the west; and
- "Low" LCT: the network fed from Meaford C BSP, which lies between Market Drayton, Stafford, and Stoke-on-Trent.

During the present reporting period, site surveys to all the 33 kV sites in the two trial areas have been completed to assess their suitability for installation and operation of communicating PQ monitor equipment. The surveys have confirmed the sites are suitable so therefore the two areas listed above have been confirmed as the trial areas for the project.

In addition to the sites within the trial areas, several other sites have been identified that feature LCTs that are not present in the trial areas such as onshore wind, battery energy storage, and large electric vehicle (EV) charging stations. These additional sites are to be included in the PQ monitor trial in order to gather valuable data on the characteristics of LCTs.

A total of 38 installation locations across 29 sites have been identified for the PQ monitor trial, of which 24 sites are within the two trial areas. The trial area and site selection activity is now complete.

2.3.4 PQ Monitor Integration

During the Design phase, this activity was concerned with assessing the feasibility of interfacing with several PQ monitors to enable remote communication of PQ data, specifying how interfaces are to be implemented and developing an overall architecture for the solution.

Progress within this reporting period

Three PQ monitors from different manufacturers were obtained for bench testing of interfaces by Nortech. The bench testing is now complete and has confirmed it is feasible to interface with each of the three monitors to obtain PQ data for remote communication. However, the testing also revealed it is not possible to remotely update the configuration of at least one of the monitors due to a proprietary protocol being used.

This activity within the Design phase is now complete.

2.3.5 PQ Analysis Automation Software

PNPQA will develop software to automate the collection, analysis, and presentation of PQ monitoring data. The related activity during this phase of the project is to develop a specification for the software.

Progress within this reporting period

During the previous reporting period, meetings were held with PQ experts from within WPD's Primary System Design (PSD) team to capture requirements for the software. These requirements have been developed in to a requirements specification for the software, which states the high-level requirements for six main features that are to be developed:

1. PQ Data Ingest: This will be a background feature that will take data from different PQ monitors and put them in to a common format within the software's time-series database, making the data available for the other analysis features.
2. PQ Trends: This will allow a user to plot a variety of PQ data from PQ monitors as time-line and bar charts.
3. PQ Dashboard: This will allow a user to get a quick overview of any recent PQ issues and the health of the PQ monitoring system.
4. PQ Heat Maps: This will allow a user to get a geographical and visual summary of PQ health within the network.
5. PQ Events Browser: This will allow a user to find PQ events that have been reported by PQ monitors, such as interruptions, and view the data associated with those events including voltage and current waveforms.
6. PQ Assessment: A tool to perform ER G5/4 harmonic connection assessments using data gathered from PQ monitors.

Detailed functional specifications have been developed for the first two features (PQ Data Ingest and PQ Trends). The functional specifications for the remaining features will be developed as part of the Build phase.

This activity within the Design phase is now complete.

2.3.6 Modelling & Studies

At this phase of the project this activity is concerned with preparations for the PQ modelling and studies work, including reviewing modelling software and defining the modelling and study requirements and aims.

Progress within this reporting period

A review of available power system analysis tools has concluded with the recommendation that DIgSILENT PowerFactory should be used as the power system analysis tool for the PNPQA project. It should provide the modelling sophistication and flexibility needed for the future-looking PQ studies that will be part of the PNPQA project.

A document has been drafted outlining the objectives and methods for the project's power system PQ studies. This document is currently being reviewed and once it is agreed, this activity within the Design phase will be complete.

2.4 Phase 2: Build

The Build phase comprises several activities to implement what was developed in the Design phase in preparation for the Trial phase. The Build phase started during the present reporting period and will continue in to the next period.

2.4.1 PQ Monitor Trial

A widescale trial of communicating PQ monitors is a major part of PNPQA and is due to start in mid-2019. This activity is concerned primarily with purchasing and building hardware, and the physical installation of PQ monitoring equipment in the trial sites.

Progress within this reporting period

During the present reporting period this activity has focused on preparing for PQ monitor installations.

PQ monitors have been ordered and delivered, and the communications hardware is being assembled. Nortech has designed enclosures for two of the different monitors that convert the units from being DIN-rail mounted and requiring wiring on site to portable units with pluggable connectors, for ease of installation. Figure 2-4 is a photo of a prototype PQ monitor enclosure alongside a Nortech Envoy communications hub.

Figure 2-4 – Envoy communications hub and prototype PQ monitor enclosure

Detailed analysis of site surveys and WPD substation information has allowed installation locations for the PQ monitors in the trial to be determined. This follows on from the trial area and site selection activity in the Design phase and includes an additional level of detail such as proposed VT and current transformer (CT) connection points and the positioning of monitors. Four different installation types have been identified and outline schematics for these have been produced. The installations differ in complexity, with the simplest being connecting a PQ monitor to existing VT secondary terminals only, up to installing a PQ monitoring panel and bringing VT and CT secondary wiring in to that panel.

Discussions with WPD's Engineering Design and Projects teams are ongoing for them to perform the PQ monitor installations and enabling works where required, such as detailed design work, wiring in existing VTs, making modifications to existing VT and CT wiring on site, or installing a PQ monitoring panel. Installations of the majority of PQ monitors for the trial is currently being delayed, but the installations will begin once resources from Projects are assigned. An existing resource will be used so the first installations of a handful of PQ monitors for the main trial can happen in April 2019.

This activity shall end during the next reporting period once all the PQ monitors are installed and the Trial phase begins.

2.4.2 PQ Monitor Integration

For the Build phase of the project, this activity is concerned with developing firmware for Nortech's Envoy communications hub that will allow the PQ monitors to be interfaced with and make the PQ monitor data available remotely.

Progress within this reporting period

Figure 2-5 shows the three different PQ monitors that are to be used for the project, from a-eberle, PSL, and Siemens. These PQ monitors use different interfaces for exposing PQ data including continuous measurements (such as harmonic voltages recorded every 10 minutes) and event recordings (such as voltage and current waveforms captured during an interruption).

Figure 2-5 – The three PQ monitors being used for the project, from left to right: the a-eberle PQI-DA smart, the PSL PQube3, and the Siemens SICAM Q200

Nortech's Envoy communications hub is being used to enable communications with the PQ monitors. The Envoy will interface with the PQ monitors to retrieve PQ data, store that locally, then upload the data to a centralised monitoring platform (Nortech's iHost) over the 4G communications network. New firmware for the Envoy has been developed to interface with the PQ monitors, and the development work is now complete for the first of the monitors. The other two monitors will be interfaced using IEC 61850 and Nortech is undertaking the development of the IEC 61850 interface as a contribution to the project.

This activity will be complete in the next reporting period once interfacing firmware for all three monitors has been developed and tested.

2.4.3 PQ Analysis Automation Software

At this phase of the project, this activity is concerned with developing the software to automate analysis of PQ, which also includes developing and agreeing detailed functional specifications for individual features of the software.

Progress within this reporting period

Development of the PQ analysis automation software started during the reporting period. Progress has been made with the data ingest feature, which now supports the import of data from the first PQ monitor. Import routines for the other two monitors will be developed once the interface firmware (for the Envoy communications hub) is complete. Development of the PQ trends feature is underway in parallel.

A functional specification for one of the next software features, the PQ dashboard, is currently being drafted by Nortech.

The PQ analysis software will form part of Nortech's iHost monitoring and control platform. A project-specific iHost server has been set up and is now operational.

This activity will continue in to the next reporting period.

2.4.4 Modelling & Studies

At this phase of the project, this activity involves building power system models for the project's PQ studies, including models of different LCTs.

Progress within this reporting period

Existing models have been obtained from WPD and these will form the basis of project-specific models that will be built during the next reporting period.

2.5 Next Steps

The activities described below are planned for the next reporting period and include the continuation of phase 2 (Build) and the start of phase 3 (Trial). Phase 1 (Design) should be completed in the early part of the reporting period.

The focus over the next reporting period is to complete the preparations for the trial and get the trial underway. Nortech will complete the development of the PQ monitor interface firmware, as well as producing communications hardware and PQ monitor enclosures. Once WPD resources are assigned, designs for the more complex PQ monitor installations will be produced, and all PQ monitors and communications hardware in the trial areas will be installed.

Development of the PQ analysis automation software will continue. Functional specifications for all the software features shall be completed and the PQ data ingest, PQ trends, dashboard, and heat map features will be developed ready for the trial.

Work on the modelling and studies aspect of PNPQA will increase. The project-specific models will be built. The study objectives and methods will be agreed within WPD and, once initial data has been collected from the trials, the first PQ studies will be undertaken.

3 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	635.4	390.0	389.2	-0.8	-0.2%
WPD Project Management	45.7	15.6	14.3	-1.3	-9.1%
Technology and Installation	553.8	120.00	116.3	-3.7	-3.2%
Contingency	123.6	0.0	0.0	0.0	-
TOTAL	**1358.5**	**352.2**	**519.8**	**-5.8**	**-1.1%**

4 Progress towards Success Criteria

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

1. Impact of LCTs on power quality and harmonics within primary networks better understood.
    - VT testing to validate the accuracy of equipment used for PQ measurements has been completed at The University of Manchester.
    - Preparations have continued for the widescale trial of communicating PQ monitors, which shall provide detailed data on the power quality within primary networks including the impact of LCTs.
    - Work has begun on developing project-specific power system models for studies in to future effects of LCTs on PQ.
2. Power quality monitors installed at trial locations and remote retrieval of data successfully demonstrated.
    - Trial area and site selection is complete, and exact installation locations have been determined.
    - An interface to enable remote communication of PQ data has been developed for one PQ monitor, and interfaces for two other monitors are being developed.
3. Tools for automating power quality data retrieval and analysis demonstrated.
    - A requirements specification for the PQ analysis automation software has been agreed.
    - Functional specifications for two of the six main features of the software have been agreed.
    - Development of the first two features of the software is underway (PQ data ingest and PQ trends).
4. Policies created to implement project outputs in WPD's business.
    - This will follow later in the project (during phase 4 – Report).

5 Learning Outcomes

5.1 Phase 1: Design

The learning across different areas of Phases 1 (Design) and 2 (Build) during the current reporting period is summarised below:

- VTs for harmonic monitoring
    - 33 kV and 11 kV VTs pass through signals at the harmonic frequencies typically measured (up to the 50th) but introduce attenuation in the output magnitude at higher frequencies, for 1-phase and 3-phase units.
    - The construction of 3-phase VTs leads to the output voltages having differences between phases.
- PQ monitors
    - Communications surveys during the site surveys revealed that no single mobile network provider could provide coverage at all sites, particularly for 4G. Therefore, roaming SIM cards will be used so the communications hub will be able to utilise whatever providers are available at each site.

- Two different monitors are being interfaced with using IEC 61850. Testing of these monitors has revealed differences in their implementation of IEC 61850, in particular the file transfer mechanism, which has prevented a single "standard" interface from being used for both monitors.
- Occasional instability of one PQ monitor has been observed, so a method of remotely triggering a power cycle has been developed. This will allow site visits to be avoided to simply reset the units.

6 Intellectual Property Rights

New foreground IPR has been generated by PNPQA in the following areas:

1. Methodology and results of VT harmonic response testing.
2. Development and application of a methodology for trial area and site selection.
3. Implementation of interfaces for retrieving PQ data off PQ monitors.
4. Requirements and designs for PQ analysis automation software.

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 WPD's 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 PNPQA 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 do not become issues wherever possible. In Table 7-1, we give details of our top five current risk by category. For each of these risks, a mitigation action plan has been identified and the progress of these are tracked and reported.

Details of the Risk	Risk Rating	Mitigation Action Plan	Progress
Lack of resources delays trial installations	Moderate	1. Identify and assign WPD resources 2. Use contractor resources	Discussions held with Projects and Engineering Design
WPD resources are unavailable	Moderate	1. Close working relationship between WPD and Nortech 2. Nortech empowered to contact alternative WPD staff for assistance	WPD to check project resourcing as project manager has a new role
Personnel are injured due to slips, trips, and falls	Moderate	1. Use teleconferencing / remote working 2. Tidy work area and pay attention when walking 3. Activity-specific risk assessments	Proximity increased as substation works will occur within the next 6 months
Personnel are electrocuted during work at substations	Moderate	1. Minimise work in substations where possible 2. Follow WPD authorisations, access, and PPE policy 3. Activity-specific risk assessments	Proximity increased as substation works will occur within the next 6 months
Personnel are injured due to incorrect manual handling	Moderate	1. Minimise manual handling work where possible 2. Ensure personnel carrying out manual handling have necessary training and PPE	Proximity increased as substation works will occur within the next 6 months

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

Table 7-2 provides a snapshot of the risk register, detailed graphically, to provide an on-going 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)	0	0	0	0	0
	Less likely to occur/Mid to long term (6-10)	1	1	2	0	0
	Very unlikely to occur/Far in the future (1-5)	0	6	7	8	0
		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	15	10	0	0	**No of instances**
Total	25				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.

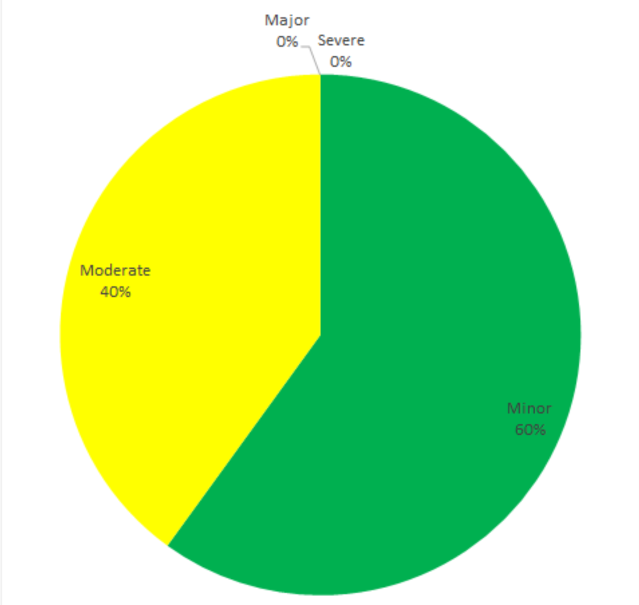

Table 7-3: Percentage of risks by category

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/2039

9 Accuracy Assurance Statement

This report has been prepared by the PNPQA Project Manager (James King), reviewed and approved by the Innovation Team Manager (Jonathan Berry).

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
BSP	Bulk Supply Point
CT	Current Transformer
EV	Electric Vehicle
IPR	Intellectual Property Rights
LCT	Low Carbon Technologies
NIA	Network Innovation Allowance
PNPQA	Primary Networks Power Quality Analysis
PSD	Primary System Design
SIM	Subscriber Identity Module
VT	Voltage Transformer
UoM	University of Manchester
WPD	Western Power Distribution