WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS

PRIMARY NETWORKS POWER QUALITY ANALYSIS

WPD_NIA_028

NIA MAJOR PROJECT PROGRESS REPORT

REPORTING PERIOD:

APR 2019 – SEPT 2019

WESTERN POWER DISTRIBUTION INNOVATION

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Contents

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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 April 2019 to September 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 third progress report, covering progress from the start of April 2019 to the end of September 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, which included 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.

During the previous reporting period (October 2018 to March 2019), two trial areas were confirmed for the project's widescale trial of communicating PQ monitors. The first trial area is the 33 kV network fed from Meaford C Bulk Supply Point (BSP), located between Stoke-on-Trent, Stafford, and Market Drayton, which is being used as the base-case low LCT trial area. The second trial area is the network fed by Ryeford BSP, centred on Stroud, which has a high penetration of LCTs and is being used as the high LCT trial area. Installations of PQ monitors have now started in the trial areas, with 24 monitors now installed and communicating.

Nortech has developed firmware for a communications hub that will enable remote communication of PQ data by interfacing with the three different PQ monitors that are being trialled as part of the project. This follows on from bench testing of the PQ monitors that was completed during the previous reporting period.

High-level requirements for software to automate the retrieval and analysis of PQ data were set during the previous reporting period, and now the development has been progressed, with four of the six main features being specified and implemented.

Objectives and methods have been agreed for the project's PQ studies.

Additional testing of the harmonic performance of VTs has taken place at The University of Manchester using new measurement equipment, following on from the tests during previous reporting periods. A technical paper summarising the results of the VT testing has been presented at 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: Steven 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)
- 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 Additional testing Sept/Oct 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

Provider	Services/goods	Area of project applicable to	Anticipated Delivery Dates
Siemens PLC	Demo PQ monitor	PQ monitor trials	Delivered October 2018
7com Ltd	PQ monitors for trials (a-eberle PQI-DA smart)	PQ monitor trials	Delivered February 2019
IMH Technologies Ltd	PQ monitors for trials (PSL PQube3)	PQ monitor trials	Delivered February 2019 Additional deliveries Sept/Oct 2019
Siemens PLC	PQ monitors for trials (Siemens SICAM Q200)	PQ monitor trials	Delivered February 2019
Accutest	Current clamps for PQ monitors	PQ monitor trials	Delivered September 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.

A technical paper presented at the CIRED conference 2019, which was used to disseminate the findings from the VT harmonic performance testing (please refer to section 2.3.2 for details). The findings from the VT testing were also disseminated at WPD's Balancing Act conference in June 2019, along with an overview of the project and results from the PQ monitoring pilot completed in 2018. Project-specific dissemination events are planned in the later stages of the project once the PQ monitor trial is complete.

2 Project Manager's Report

2.1 Project Background

PNPQA is split in to four phases:

1. Design – this first phase of the project included 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 a single activity from the first phase (Design) running concurrently. The following progress made:

- Re-testing the harmonic performance of VTs has been started at The University of Manchester, using a new measurement system that should yield more accurate results;
- Nortech has developed interfaces for their Envoy communications hub that enables remote communication of PQ data from the three different PQ monitors being used in the trial;
- Installations of PQ monitors for the main trials have progressed, with resources assigned and 24 of 32 monitors being installed at sites within WPD's Primary network.
- Designs have been prepared for six sites where the PQ monitors will be installed within fixed PQ monitoring panels, and the panels have been manufactured.
- Several sites in the 11 kV network within the main trial areas have been identified for installation of PQ monitoring as part of the project's trials.
- The software to automate the retrieval and analysis of PQ data has been progressed, with four of the six main features being specified and developed; and
- Objectives and methods have been agreed 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 included several activities that ran from the start of the project up to the initial part of the subsequent Build phase. Except for VT testing, all the Design phase activities were completed by the end of the previous reporting period.

2.3.1 Monitoring Pilot

A widescale trial of communicating PQ monitors is a major part of PNPQA and will start in November 2019. In order to gain some early learning with a communicating power quality monitor, a pilot trial of with a single monitor was completed in mid-2018.

Progress within this reporting period

The PQ monitor used for the pilot was left in situ at Meaford C substation following the pilot trial. The monitor was not the same as those used for the main monitoring trial and was not supported in the software being developed for the project so it was removed and replaced with a PSL PQube3 for the main trial in September 2019.

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 report for the previous reporting period included the results of harmonic testing performed by The University of Manchester (UoM) on four VTs representative of those used by WPD. During the present reporting period, a technical paper on those results was presented at the CIRED conference. The paper and presentation engaged the technical experts that were in attendance and useful feedback was received regarding other work (with both similar and also dissimilar results) and on the test setup.

The UoM have upgraded their Data Acquisition (DAQ) system and the voltage probes on the VT secondary (output) side, and the VT tests have been re-run using this new system. The new DAQ system has different input circuitry that is better suited to complement the measurement transducers used for the testing. Additionally, the range of test frequencies has been increased to include the 100th harmonic order (5 kHz).

At the end of the reporting period, the UoM have re-tested one VT, a 3-phase 11 kV cast resin VT from a metering unit.

Figure 2-1 shows the magnitude frequency response up to the 100th harmonic of each phase of the 11 kV 3-phase VT from the laboratory testing at the UoM using the new DAQ system, and up to the 50th harmonic using the old DAQ system. The y-axis scale is terms of the *normalised ratio*, which quantifies the relationship between the actual output of the VT and the expected output based on the nameplate ratio. A value 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 magnitude frequency response shown in Figure 2-1 has similar patterns in the results from the old and new DAQ systems.

Firstly, as the frequency increases, there is increasing attenuation of the output signal, shown by the normalised ratio decreasing in Figure 2-1. Although the downward trend is similar, the attenuation is less with the new DAQ system, and at the 50th harmonic the minimum normalised ratio is 0.515 (L2) rather than 0.337 (L2) with the old DAQ system.

A second similarity in the results shown in Figure 2-1 is that the pattern of the ordering of the phases and the points at which they cross are approximately the same. Using the old DAQ system, L2 starts with higher values than L1 and L3, and then noticeably diverges below L1 and L3, and has the lowest values at 1.4 kHz and beyond. With the new DAQ system L2 does start higher and then crosses L1 and L3 at a similar frequency, but the divergence is less and all phases have similar values up to around 3.5 kHz. At 3.5-4.5 kHz the behaviour changes and the response curves diverge and then converge in reversed order, changing from (highest values first) L3, L1, L2 to L2, L1, L3.

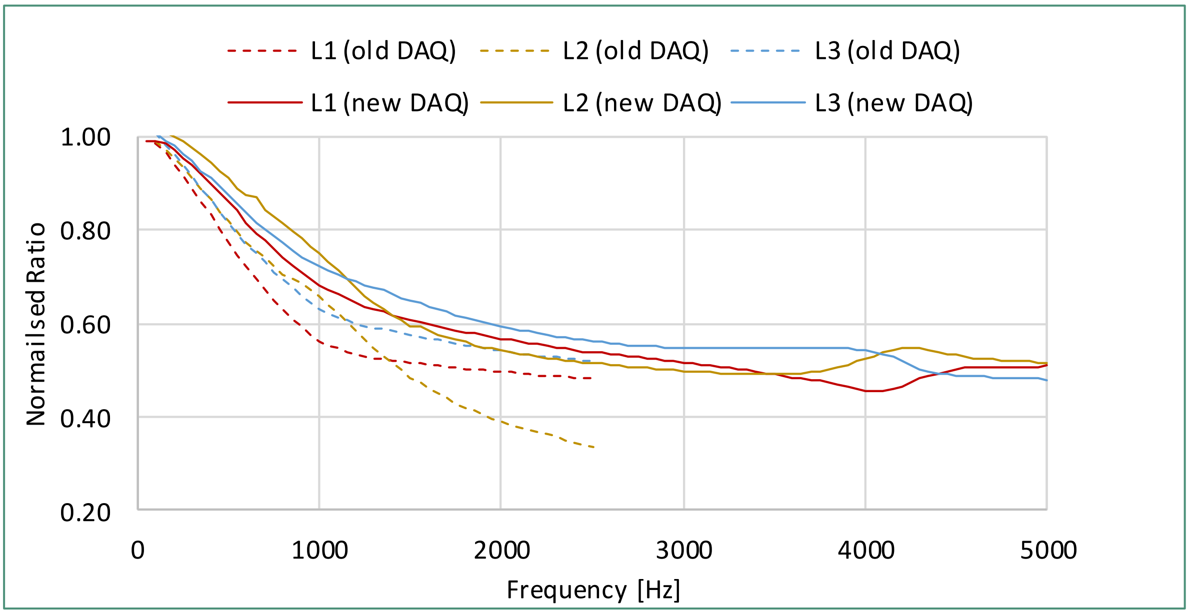

Figure 2-1: Magnitude frequency response of 11 kV 3-ph VT

The phase frequency response results shown in Figure 2-2 shows a noticeable difference between the results obtained with the old and new DAQ systems. With the new DAQ system, L1, L2, and L3 provide similar results to each other, whereas with the old DAQ system L2 had a completely different phase frequency response to L1 and L3. Similar to the magnitude phase response, there is a change in behaviour at 3.5-4.5.

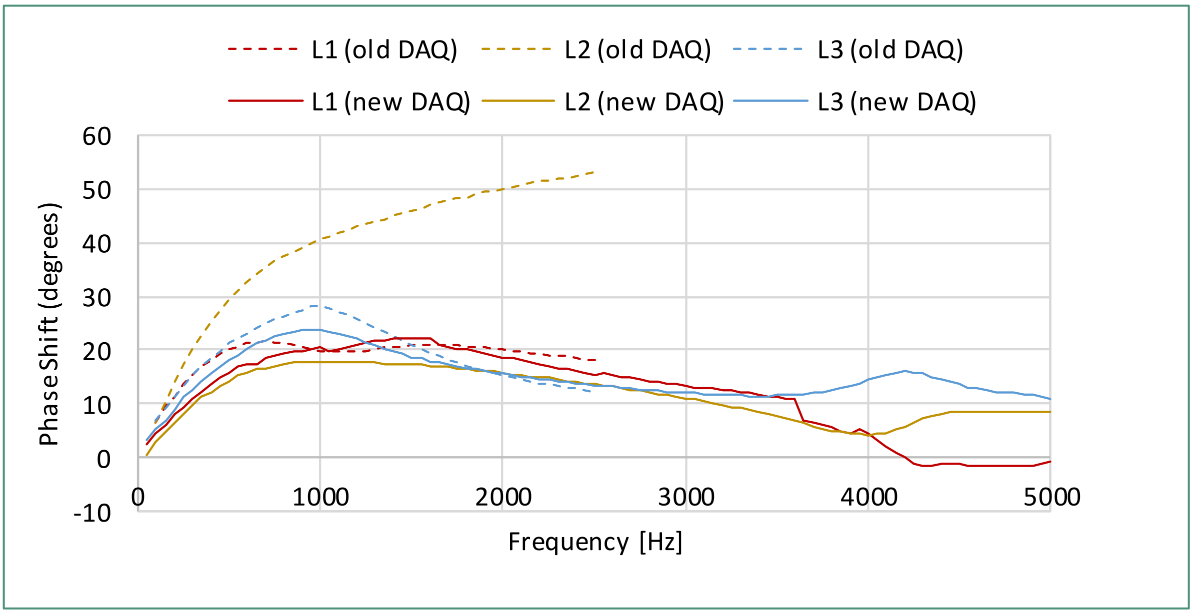

Figure 2-2: Phase frequency response of 11 kV 3-ph VT

The changes seen in the results using the new DAQ system compared with the results using the old DAQ system are likely due to differences in the input circuitry and may also be influenced by using different measurement transducers on the secondary side of the VT. Although there are differences – particularly for the phase frequency response – the most important finding remains the same: the tests indicate that VTs attenuate the magnitude of higher-frequency harmonics, to the extent where the output at the 50th harmonic could be around 50% of the value that would be expected from the nominal turns ratio of the VT. The implication of this is that harmonic voltage measurements from VTs may be under-reporting the actual harmonics on the system.

The UoM plans to re-test the two 1-ph 33 kV VTs, and once this is done the VT testing activity in the Design phase will be complete. Due to the potential significance of the findings, during the Trial stage additional VT testing at a separate facility is planned to validate the results of the testing done so far, and also take in to consideration confounding factors such as the burden placed on the VT secondary circuits and the type of wiring used.

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. This activity ran to select the two network areas and sites within them to be used in the trial.

Progress within this reporting period

This activity completed in the previous reporting period.

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

This activity with the Design phase completed in the previous reporting period.

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 was to develop an overall requirements specification for the software.

Progress within this reporting period

This activity with the Design phase completed in the previous reporting period.

2.3.6 Modelling & Studies

At this phase of the project this activity was 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 document has been prepared and agreed outlining the objectives and methods for the project's power system PQ studies. The studies will be performed on models representing the two main trial areas for the project, and will consider locational, temporal, technological, and scale effects of increased LCT penetrations on PQ up to the year 2030.

The activity within the Design phase is now 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 previous 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 will be starting in November 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

Two areas are being used for the PQ monitor trials, which were selected through the trial area and site selection activity during the Design phase. The two areas are 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.

There are two main installation types for the PQ monitors in the PNPQA project. The first type is the "plug & play" installations where non-fixed monitors are temporarily connected to VT secondary circuits using test leads and, optionally, currents are monitored via clip-on sensors around CT secondary circuit wiring. The majority of the PQ monitor installations within the project are the "plug & play" type – totalling 39 monitors across 32 sites. There are six sites where a "plug & play" type installation is not possible due to the switchgear used, and at these sites a fixed "PQ panel" will be installed, which will consist of a wallbox containing 1 or 2 monitors and fixed wiring to tap in to VT and CT secondary circuits.

Installations of PQ monitors in the two trial areas were initially planned to complete in the first half of 2019; however, the installations have had to be delayed to later in 2019 due to two main factors. The first factor leading to a delay was the timescales associated with identifying, assigning, and then awaiting installation resources to become available for both types of installations. Resources were assigned during the present reporting period and the majority of the plug & play PQ monitor installations are now complete at the BSPs and Primaries within the two trial areas. is an example of plug & play installation at Meaford C that was completed near the end of the reporting period.

The second factor leading to a delay in installing PQ monitors for the main trial was the engineering design and equipment manufacturing times associated with the PQ panels. During the reporting period, designs for the panels were prepared, including general arrangement drawings (an example of this is shown in Figure 2-3), wiring diagrams, and site-specific interface drawings. The panels have been manufactured and are waiting pre-commissioning prior to installation on site.

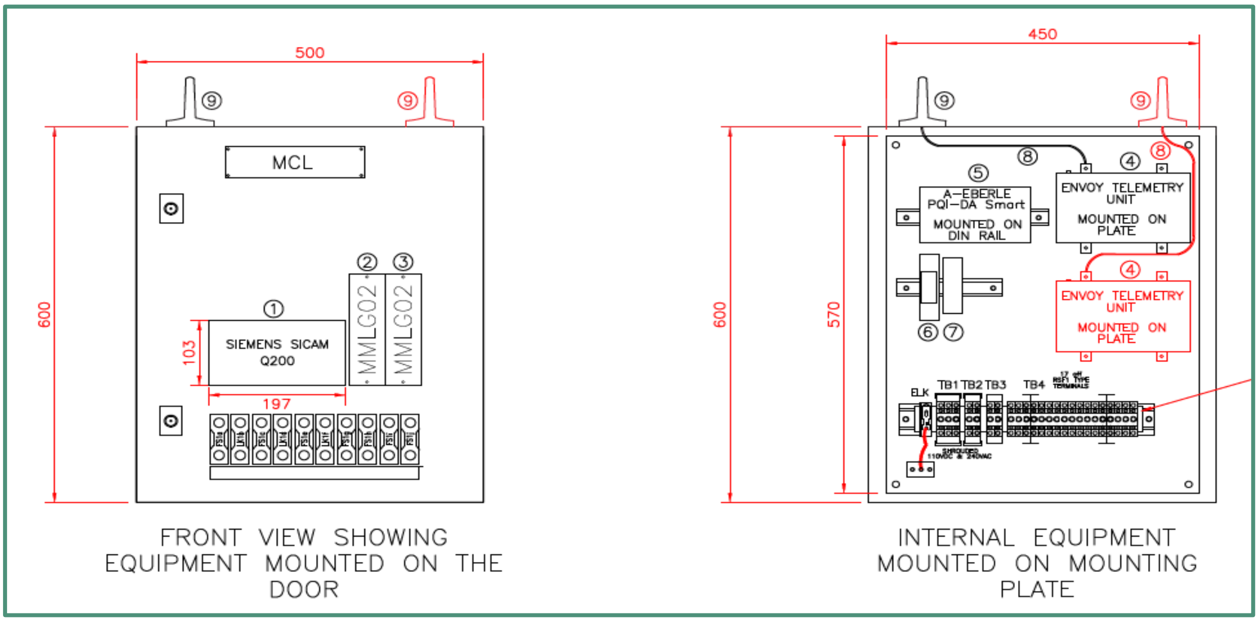

Figure 2-3: Example plug & play PQ monitor installation

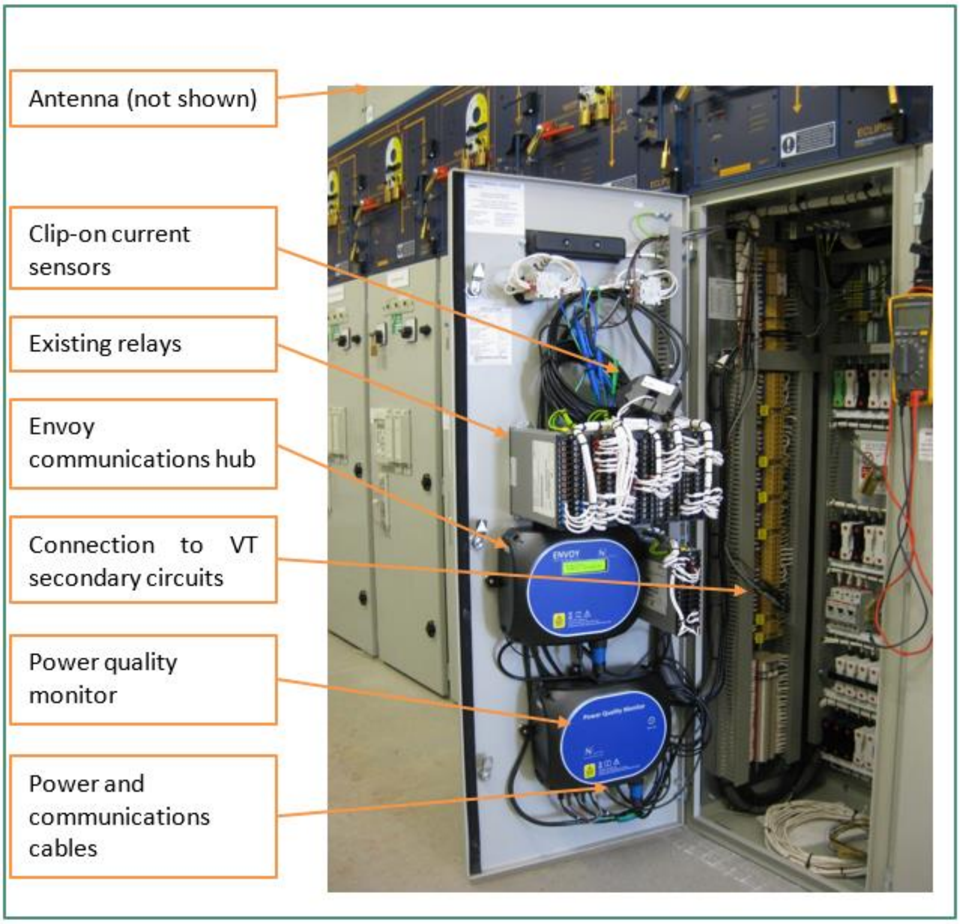

Figure 2-3: Example general arrangement drawing for PQ panel

Within the trial areas, the focus of the PQ monitoring trial is the 33 kV Primary network, and that is where the effort has been concentrated on in preparing for the trials; however, the project's scope also includes monitoring of a small number of 11 kV secondary substations to help understand the PQ interactions between the two voltage levels. During the PQ monitor installation planning it emerged that 33 kV PQ monitoring was not possible at 3 of the Primary substations in the Meaford C trial area due to major works on site or lack of space, reducing the PQ visibility in that area. Based on the original scope and the need to maximise PQ visibility within the trial areas, a second site selection exercise was undertaken to identify several 11 kV sites where PQ monitoring would be installed as part of the project's trials. A total of 12 sites within the trial areas at 11 kV are planned to have "plug & play" PQ monitoring installed.

The main trial area sites are supplemented by a few sites from wider within WPD's network that will add valuable data to the project, which have examples of LCTs that were not found within the main trial areas. The LCTs represented by the other sites include energy storage, a wind farm, and EV rapid chargers.

The PQ monitor installation status is summarised in **Error! Reference source not found.**, which shows the total number of monitors planned for each area or group of sites along with the number installed at the end of the reporting period (and including the week commencing 30th September 2019). The "plug & play" installations are complete at most 33 kV sites, whilst the PQ panel and 11 kV "plug & play" installations remain to be completed.

Area / Site(s)	Plug & Play Monitors Installed / Total	PQ Panel Monitors Installed / Total
Ryeford area (high LCT) BSP & Primaries (33 kV)	14 / 15	0 / 5
Ryeford area (high LCT) Distribution substations (11 kV)	0 / 3	-
Meaford C area (low LCT) BSP & Primaries (33 kV)	7 / 7	0 / 2
Meaford C area (low LCT) Distribution substations (11 kV)	0 / 9	-
Energy storage	2 / 3	-
Wind farm	1 /1	-
EV rapid charger	0 / 1	

Table 2-1: Summary of PQ monitor installation status

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 2-4 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 2-4: 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 remote communications with the PQ monitors. The Envoy interfaces 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 was completed during the present reporting period. The final testing of the interfaces to the a-eberle and Siemens monitors has been delayed until the next reporting period in order for firmware to be shipped and not delay the PQ monitor installations.

This activity will finish early in the next reporting period once the final testing of the monitor interfacing firmware is complete.

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

The PQ analysis automation software is being implemented in to Nortech's iHost monitoring and control platform and includes six main features:

1. PQ Data Ingest: This is a background feature that takes data from different PQ monitors and puts 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 allows a user to plot a variety of PQ data from PQ monitors as time-line and bar charts.
3. PQ Dashboard: This allows 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 allows a user to get a geographical and visual summary of PQ health within the network.
5. PQ Events Viewer: 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.

During the previous reporting period, detailed functional specifications were completed for the first two features, PQ Data Ingest and PQ Trends. These features have been implemented during the current reporting period and are now deployed to the project's iHost server. This has allowed data from the PQ monitors already installed as part of the project to be displayed and interrogated. Figure 2-6 is an example of a PQ Trend showing voltage harmonics for a single phase: at the top is a time-series plot of the 2^{nd}-50^{th} harmonic orders over a week, whilst below that is a bar-chart summarising the 95^{th} percentile values of the same harmonic data.

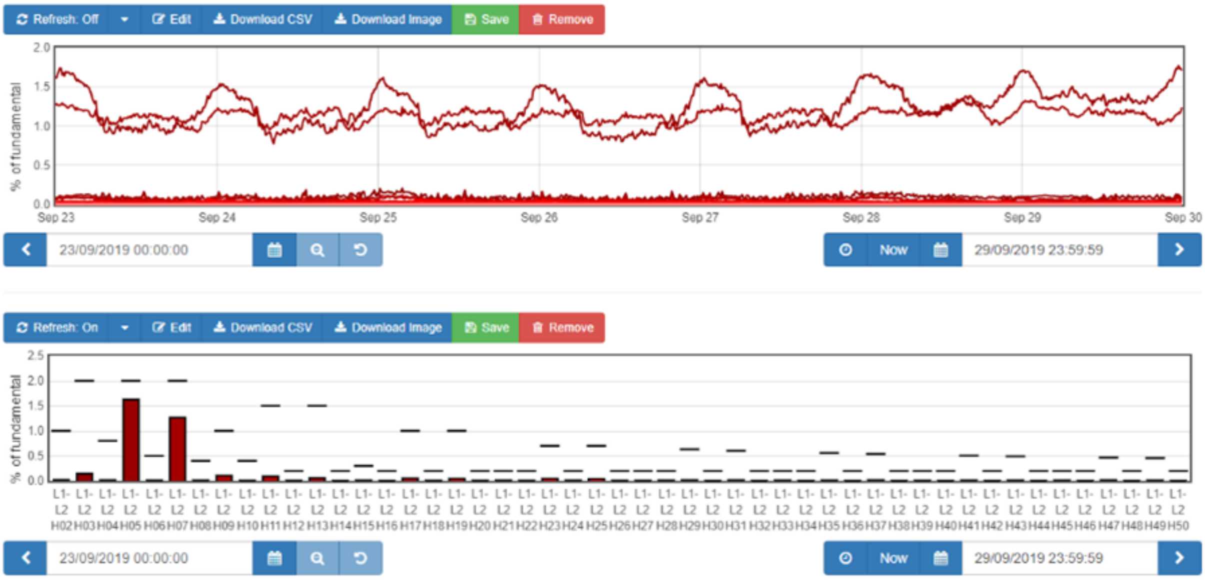

Figure 2-6: Example PQ Trend showing a week of harmonic data as time-series and bar plots

The PQ Dashboard and PQ Heat Maps features were specified and implemented during the current reporting period. They are due to be deployed to the iHost server early in the next reporting period so examples will be provided in the next report.

Work has started on the final two features, the PQ Events Viewer and PQ Assessment Tool. A draft functional specification for the PQ Events Viewer has been prepared and is currently under review.

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 and supporting data have been obtained from WPD and these will form the basis of project-specific models that will be built during the next reporting period. This activity has been delayed due to focusing on the PQ monitor installations.

2.5 Next Steps

The activities described below are planned for the next reporting period and will begin with the start of phase 3 (Trial). Phase 1 (Design) should be completed in the early part of the reporting period, whilst phase 2 (Build) will continue for most of the next reporting period.

The PQ monitor installs at 33 kV for the main trial should be completed in the early part of the next reporting period, at which point the trial will be underway. The installation of PQ monitors at 11 kV sites within the trial areas will be planned and executed. Additionally, testing of the communications hubs' interfaces to the PQ monitors will be finalised.

Development of the PQ analysis automation software will continue. The remaining two features (PQ Events Viewer and PQ Assessment Tool) will be specified and developed, so the software will be complete and ready for trialling.

The modelling and studies aspect of PNPQA will continue, with the project-specific models being completed and then used to undertake initial studies using existing PQ data.

The VT testing activity will be continued, with work taking place to define the scope and progress VT harmonic performance testing at a separate laboratory, with the aims of validating and also extending the testing already undertaken as part of the project.

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	436	419.1	16.9	3.88%
WPD Project Management	45.7	24.5	25.2	-0.7	-2.86%
Technology and Installation	553.8	152.6	151.7	0.9	0.59%
Contingency	123.6	0.0	0.0	0.0	-
TOTAL	**1358.5**	**613.1**	**596**	**17.1**	**2.79%**

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.
    - Further VT testing to validate the accuracy of equipment used for PQ measurements has been completed at The University of Manchester.
    - Most of the 33 kV PQ monitors for the widescale trial of communicating PQ monitors have been installed. These monitors shall provide detailed data on the power quality within primary networks including the impact of LCTs.
    - The objectives and methods have been agreed for the project's power system studies in to future effects of LCTs on PQ
    - Work has continued developing project-specific power system models.
2. Power quality monitors installed at trial locations and remote retrieval of data successfully demonstrated.
    - 24 out of 32 PQ monitors at 33 kV for the main trial have been installed.
    - Interfaces for the three types of PQ monitors being used in the trial have

been developed.
   - Data has successfully been remotely retrieved from all installed PQ monitors.
3. Tools for automating power quality data retrieval and analysis demonstrated.
   - A requirements specification for the PQ analysis automation software has been agreed.
   - Four of the six main features of the software have been specified and developed.
   - A functional specification for the fifth feature (PQ Events Viewer) has been drafted and is under review.
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

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

- VTs for harmonic monitoring
   - Following re-testing with improved equipment, the previous finding still holds that VTs pass through signals at the harmonic frequencies typically measured (up to the 50^{th}) but introduce attenuation in the output magnitude at higher frequencies.
   - Close attention must be paid to the frequency response of the measurement system in addition to the VT under test, as this can influence the results.
- PQ monitors
   - The communication hubs' interface to two of the PQ monitors relies on frequently polling and collecting data using the IEC 61850 protocol. For at least one of the monitors this approach can lead to small amounts of data being lost as the monitor is sometimes unable to reply to all requests. Furthermore, if communication between the monitor and communication hub is lost for a period, almost all monitoring data for the period cannot be subsequently retrieved using the IEC 61850 protocol. As the PQ monitoring data does not need to be transmitted continuously, transfer of the data via file transfer is preferred as it can be carried out asynchronously, is more robust to temporary communications loss, and is less resource-intensive.
   - The plug & play PQ monitor installations have been sped up by pre-configuring and pre-commissioning (using secondary injection) the monitors and communications hubs prior to going to site. This has reduced the complexity of install checks on site to a simple single A4-sized checklist.

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.
5. Implementation of 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 26 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
Risk of system trip during substation works	Moderate	1. Identify activities which present risk of trip and determine mitigation plan 2. WPD Projects doing substation work	Proximity raised as installs are taking place
Lack of resources delay trial installations	Moderate	1. Escalate to reduce timescales 2. Simplify installations 3. Identify and assign other WPD resources 4. Use contractor resources	Installations underway and final 33 kV installations have assigned resources
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 raised as substation works underway / planned soon
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 raised as substation works underway / planned soon
Personnel are injured / killed due to falling from height	Moderate	1. Minimise work at height where possible. 2. Ensure personnel have necessary training and PPE 3. Activity-specific risk assessments	Proximity raised as substation works underway / planned soon

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)	0	3	2	0	0
	Very unlikely to occur/Far in the future (1-5)	0	7	6	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	**16**	**10**	**0**	**0**	**No of instances**
Total	**26**				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.

% of risks by category

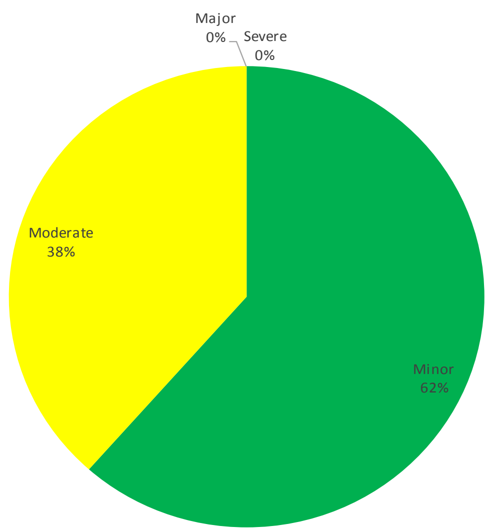

Table 7-3: Percentage of risks by category

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 by WPD Project Manager (Steven Pinkerton-Clark) and approved by the WPD 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
DAQ	Data Acquisition
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