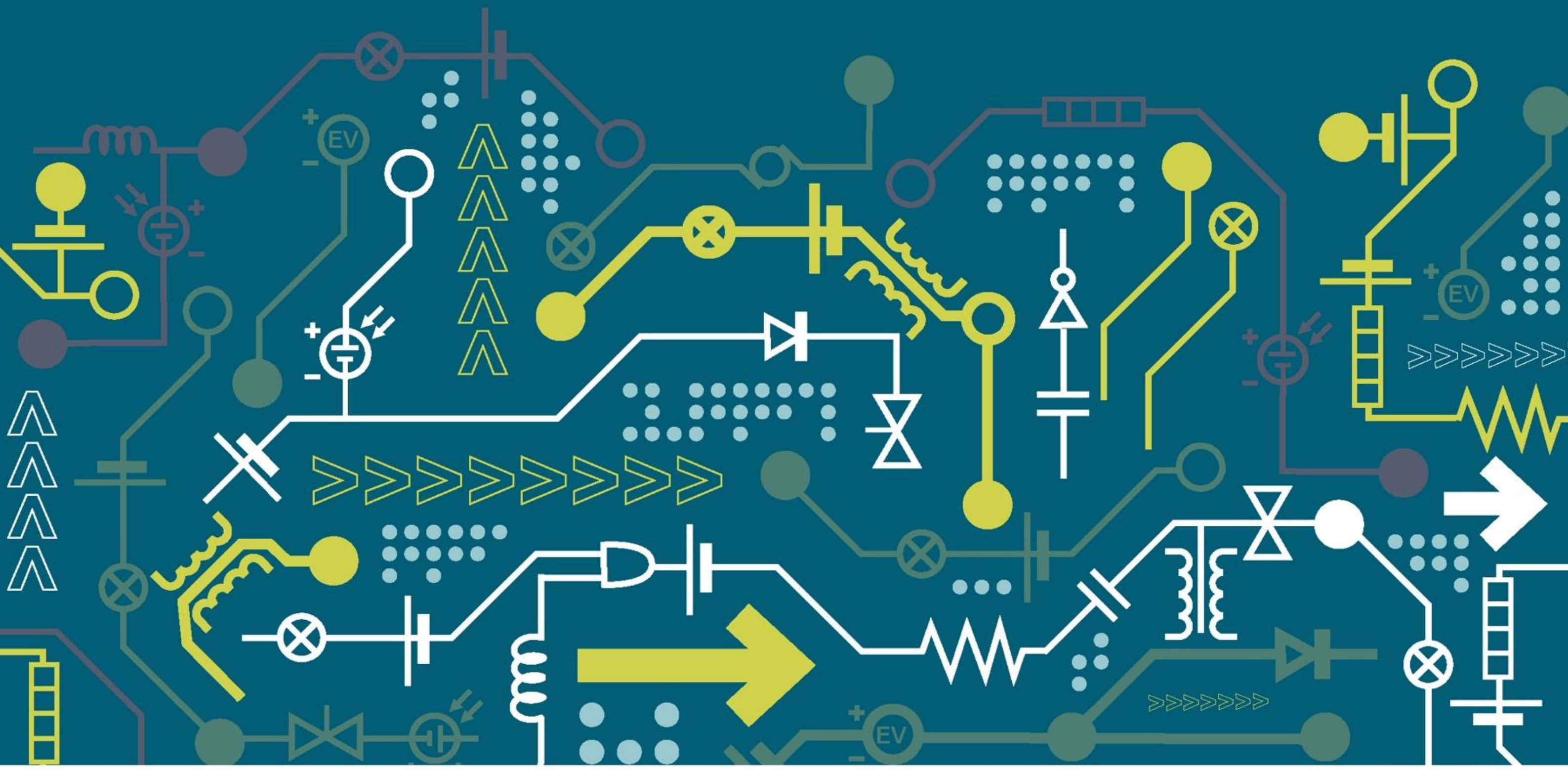
WPD INNOVATION

Primary Networks Power Quality Analysis

NIA_WPD_028

Six Monthly Progress Report
Reporting Period: Oct 2019 – Mar 2020



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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 October 2019 to March 2020.

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 102 GW[1], which is nearly 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.

1.2 Project Progress

This is the fourth progress report, covering progress from the start of October 2019 to the end of March 2020.

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

1. Design – this first phase 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;

[1] National Grid, Future Energy Scenarios (2019 and 2017): http://fes.nationalgrid.com/
[2] https://www.gov.uk/government/publications/clean-growth-strategy

2. Build – this the most recent phase, which included 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 current phase of the project and combines a wide scale 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;

4. Report – this is the final phase of the project, and includes dissemination events, drafting policies for Business-as-Usual adoption, and producing the close down report.

During the previous reporting period (April 2019 to September 2019), communicating PQ monitor installations took place within the project's two trial areas: 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; and 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. A total of 24 monitors were installed and communicating at the end of the previous reporting period. In addition, four of the six main features of the software to automate the retrieval and analysis of PQ data were implemented, and objectives and methods had been agreed for the project's PQ studies.

The project's PQ monitor installations have now been completed, including sites with fixed PQ monitor panels and several 11 kV sites. The total number of monitors installed and communicating is 46, and the PQ monitor trial is now underway. The scope of analysing the monitored PQ data has been defined and some initial analysis undertaken using the first month of data.

The PQ analysis automation software development has progressed. All functional specifications are complete for the six main features, and a key element of the fifth main feature has been developed.

Power system and LCT models have been constructed for future-looking power system studies of the potential PQ impacts of increased LCTs.

The University of Manchester has completed re-testing the harmonic performance of VTs using new measurement equipment, following on from the tests during previous reporting periods. A second laboratory has been engaged to perform follow-on testing to confirm and extend the results gained so far.

1.3 Project Delivery Structure

1.3.1 Project Review Group

The PNPQA Project Review Group meets on a bi-annual basis and has the role 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); and
    - Simon Hodgson (Technical Manager).

1.4 Procurement

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

Table 1-1: Project procurement status

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	Delivered June 2018 – December 2019
National Physical Laboratory	Further VT harmonic performance testing	VT testing	April 2020 – September 2020
(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 (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 & Sept/Oct 2019
Siemens plc	PQ monitors for trials (Siemens SICAM Q200)	PQ monitor trials	Delivered February 2019
Accutest Ltd	Current clamps for PQ monitors	PQ monitor trials	Delivered September 2019

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 the project's 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.

Project-specific dissemination events are planned in the later stages of the project once the PQ monitor trial is nearly complete.

2 Project Manager's Report

2.1 Project Background

PNPQA is split in to four phases:

- 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;

- Build – this second phase 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 and LCT models for future-looking PQ studies;

- Trial – this is the current phase and combines a wide scale trial of communicating power quality monitors with software to automate the collection and analysis of PQ data, along with modelling and analysis to understand the future impact of increased LCTs on Primary Networks; follow-up VT harmonic testing has also now been added to this phase; and

- 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 third phase (Trial), with a single activity from the second phase (Build) running concurrently. The following progress has been made:

- Re-testing the harmonic performance of VTs has been completed at The University of Manchester (UoM), using a new measurement system that should yield more accurate results;
- A second laboratory has been engaged to perform follow-up VT testing, to validate and extend the earlier testing done by the UoM;
- Nortech has completed testing interfaces for their Envoy communications hub that enables remote communication of PQ data from the three different PQ monitors being used in the trial;
- All the power quality monitor installations planned for the project have been completed, with 46 monitors now installed;
- The scope for analysing PQ monitor trials data has been defined and agreed;
- Initial analysis of the first month of monitoring data has been performed;
- Software to automate retrieval and analysis of PQ data has been progressed, with all six main features specified and most development work for the fifth main feature being completed; and
- Power system and LCT models have been constructed for future-looking power system studies of the potential PQ impacts of increased LCTs.

More detail of the progress within each of these activity areas for phase 1 is provided in the subsections within section 2.3 below, for phase 2 within section 2.4, for phase 3 within section 2.5, and for phase 4 within section 2.6. Next steps for within the next reporting period are described in section 2.7.

2.3 Phase 1: Design

All activities in Phase 1 were completed in previous reporting periods, with the exception of the VT testing at The University of Manchester so only that activity is reported on below.

2.3.1 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

During the previous reporting period, The University of Manchester (UoM) had upgraded their Data Acquisition (DAQ) system and the voltage probes on the VT secondary (output) side, to make an overall measurement system better suited to complement the measurement transducers used for the testing. The new DAQ system had been used to re-test the harmonic response of one VT (a 3-phase 11 kV cast resin VT from a metering unit) up to the 100^{th} harmonic order (5 kHz).

During the present reporting period, the new DAQ system has been used to re-test two other VTs, both 1-phase 33 kV units.

The magnitude frequency responses from the UoM laboratory testing for the first and second 1-phase 33 kV VTs are shown in Figure 2-1 and Figure 2-2 respectively The figures show the results obtained up to the 100^{th} harmonic using the new DAQ system, and up to the 50^{th} harmonic using the old DAQ system. The y-axis scales are in 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 results for the 1-ph 33 kV VTs are consistent with the trends seen in previous results for the 3-phase 33 kV VT. As frequency increases, a reduction of normalised ratio is seen using both the new and old DAQ system; however, the reduction is less pronounced when measured using the new DAQ system. At the 50^{th} harmonic (2.5 kHz), the normalised ratio is 53.3% of the expected value for VT #1 (compared with 39.1% when measured using the old DAQ system), whilst for VT #2 the normalised ratio is 53.0% of the expected value (compared with 28.2% when measured using the old DAQ system).

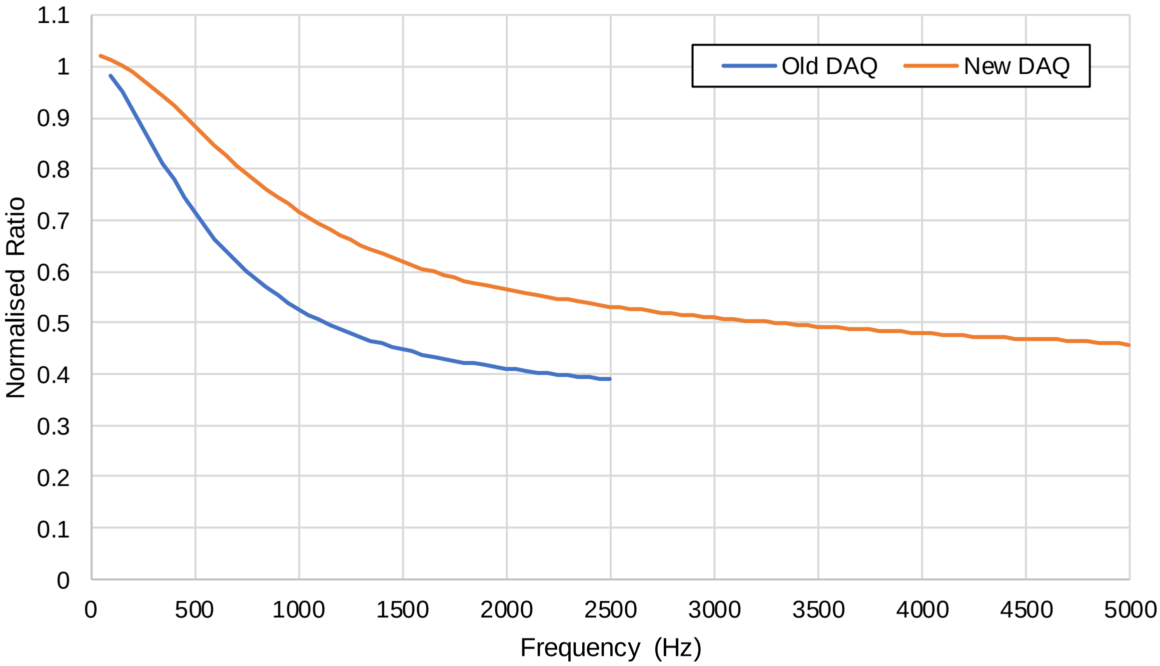

Figure 2-1: Magnitude frequency response for 1-ph 33 kV VT #1

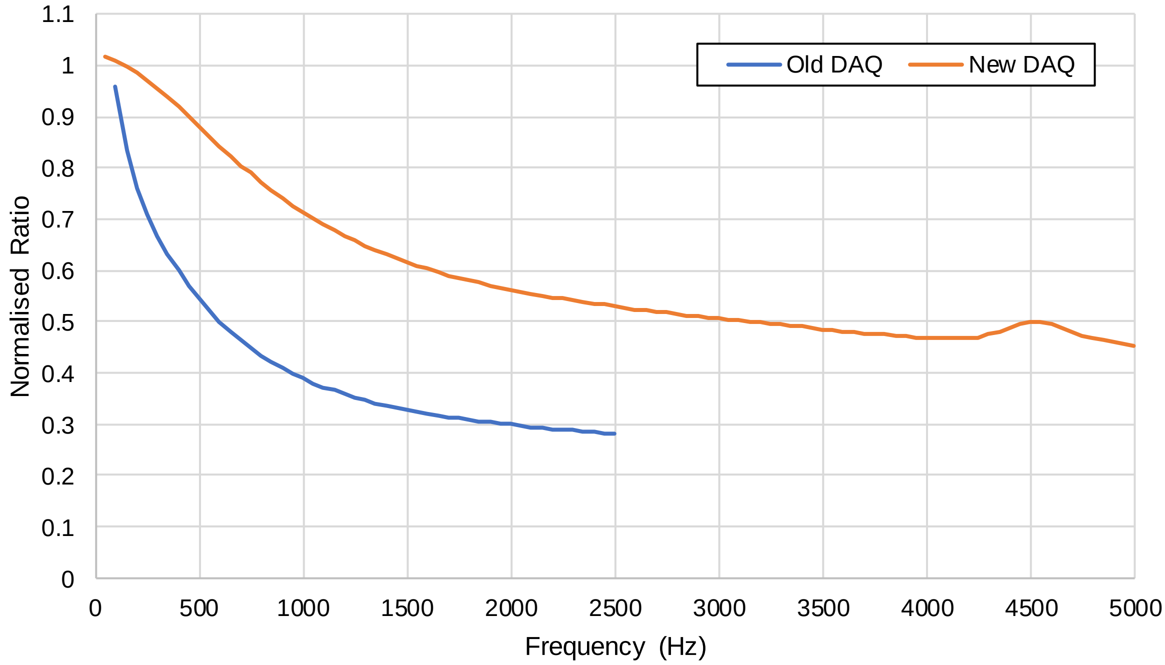

Figure 2-2: Magnitude frequency response for 1-ph 33 kV VT #2

As noted in the previous report, 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. However, 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 VT testing activity by the UoM during the Design phase is complete but follow-up testing at a separate laboratory is planned – please refer to Section 2.5.4 for more details.

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. Most activities for the Build phase completed during the present reporting period, except PQ analysis automation software development, which 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 started in December 2019. This activity has been 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 was not possible due to the switchgear used, and at these sites a fixed “PQ panel” has been installed, which consist of a wallbox containing 1 or 2 monitors and fixed wiring to tap in to VT and CT secondary circuits.

During the present reporting period all six PQ panel installations were competed: 4 at sites within the Ryeford trial area, and 2 at sites within the Meaford C trial area. Short outages of substation equipment were necessary as existing VT and CT circuits had to be modified to interface with the panels. Figure 2-2 shows an example of an installed PQ panel (in particular, the panel at Hookgate primary in the Meaford C trial area) and the interposing CTs that sit between existing CT secondary circuits and the CT secondary circuits running to the PQ panels.

(a) PQ panel with PQ monitor

(b) Interposing CTs

Figure 2-3: Example PQ panel and interposing CTs

In addition to the 6 PQ panels, an additional 15 “plug & play” monitors have been installed within the present reporting period. The majority of these were at 11 kV distribution substations of interest within the trial areas (9 in the Meaford C area, 3 in the Ryeford area) that add extra visibility and useful data on LCTs to the project’s trials. Figure 2-3 shows an example of one of these 11 kV installations. Two other 11 kV installations were made outside the main trial areas to capture data from LCTs of interest; in particular, a battery energy storage unit and a bank of EV rapid chargers. In addition, one 33 kV monitor install was completed in the Ryeford area that had been delayed from the last reporting period due to faulty equipment.

Figure 2-4: Plug & play PQ monitor installation at an 11 kV distribution substation

Table 2-1 is a summary of the installation status of the PQ monitors for the project across the different trial areas and sites, and voltage levels.

Table 2-1: Summary of PQ monitor installation status

Area / Site(s)	Plug & Play Monitors Installed / Total	PQ Panel Monitors Installed / Total
Ryeford area (high LCT) BSP & Primaries (33 kV)	15 / 15	5 / 5
Ryeford area (high LCT) Distribution substations (11 kV)	3 / 3	-
Meaford C area (low LCT) BSP & Primaries (33 kV)	7 / 7	2 / 2
Meaford C area (low LCT) Distribution substations (11 kV)	9 / 9	-
Energy storage	3 / 3	-
Wind farm	1 / 1	-
EV rapid charger	1 / 1	-
SUB-TOTALS	**39 / 39**	**7 / 7**

This activity is now complete.

2.4.2 PQ Monitor Integration

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

Progress within this reporting period

Nortech's Envoy communications hub is being used to enable remote communications with the three different PQ monitors being used within the project. New firmware for the Envoy has been developed for interfacing 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. Development work was completed in the previous reporting period and during the present reporting period the final testing of the interface firmware was successfully completed.

This activity is now 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 specifying and then developing individual features within 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:

- 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;
- PQ Trends: This allows a user to plot a variety of PQ data from PQ monitors as time-line and bar charts;
- PQ Dashboard: This allows a user to get a quick overview of any recent PQ issues and the health of the PQ monitoring system;
- PQ Heat Maps: This allows a user to get a geographical and visual summary of PQ health within the network;
- 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 from COMTRADE files; and
- PQ Assessment: A tool to perform ER G5/4 harmonic connection assessments using data gathered from PQ monitors.

During previous reporting periods, detailed functional specifications were completed the first four features, and the PQ Data Ingest (for PQube3 data) and PQ Trends features were developed and deployed to the project's iHost server.

The PQ Dashboard and PQ Heat Maps features were developed in the last reporting period and have since been deployed to the project's iHost server.

Figure 2-5 is an example of the PQ Dashboard. The top two rows summarise the state of monitored PQ in the power system over different time ranges (previous day, previous 7 days, and previous 30 days), and the bottom two rows summarise the state of the PQ monitoring system.

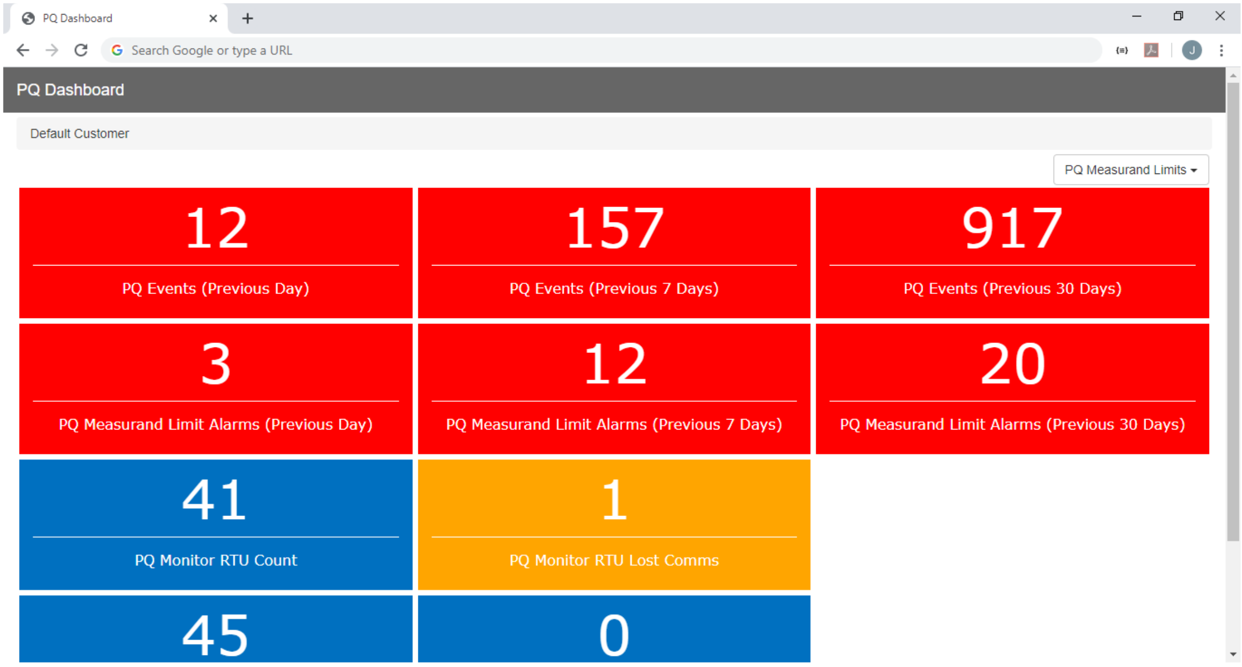

Figure 2-5: Example of the PQ Dashboard

Figure 2-6 is example of a PQ Heat Map, showing variation of 5th harmonic voltages across the trial sites, for a set time period (in this case, the previous 7 days). The colour of the marker for each site indicates the 95th percentile value of the 5th harmonic voltage at each site, from blue (low) to red (high).

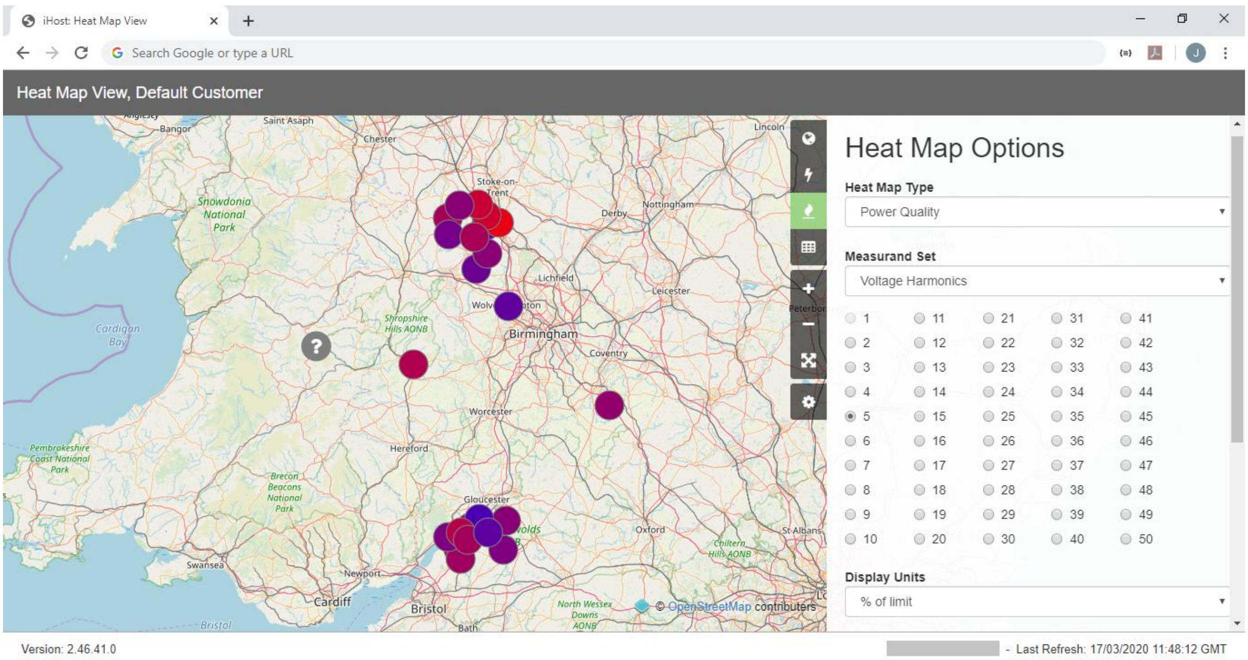

Figure 2-6: Example PQ Heat Map, showing variation in 5th harmonic voltages across the trial sites

During the present reporting period the PQ Events Viewer has been progressed, with a functional specification being drafted and finalised, and the events recording viewer element has been developed and deployed. Figure 2-7 is an example of the events recording viewer in use, displaying voltage and current waveform data. The events timeline browser element of the PQ Events Viewer will be completed and deployed during the next reporting period. A mock-up of this feature is shown in Figure 2-8.

Figure 2-7: Events Recording Viewer displaying a voltage and current waveform data

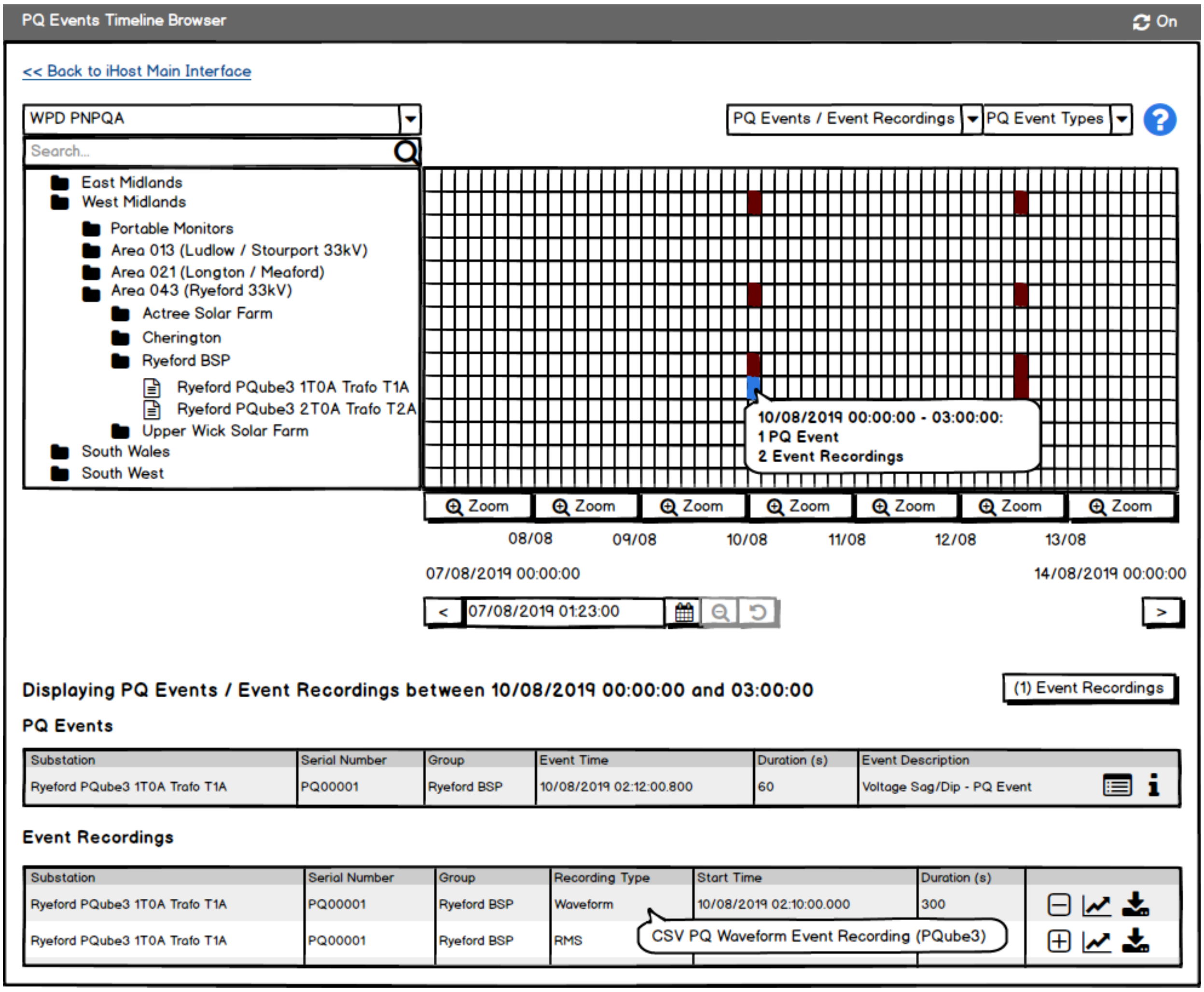

Figure 2-8: Mock-up of the PQ Events Timeline Browser

The PQ Data Ingest feature has been updated to support ingesting data from the a-eberle PQI-DA smart and Siemens SICAM Q200 power quality monitors, in addition to the existing support for the PSL PQube3 monitor. The data ingest has been verified by comparing data from examples of each monitor, which are installed to monitor the same circuit at Netherhills Primary.

A functional specification has been prepared and agreed for the sixth main feature, the PQ Assessment Tool. This feature will be developed during the next reporting period. Two additional reporting features have been added into the scope of the software: 1) an EN 50160 report, and 2) a ER G5/4 background data report. These reporting features will be specified and developed during the next reporting period.

This activity will continue into the next reporting period.

2.4.4 Modelling & Studies

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

Progress within this reporting period

Project-specific power system models have been constructed in DIgSILENT PowerFactory to represent the two main trial areas. The models are focused on the Primary networks (33 kV) but also include upstream 132 kV and busbars representing the interface points with the transmission system and with the 11 kV distribution system. The models were constructed by replicating network schematics within PowerFactory, for example Figure 2-8 is an example of a substation schematic built in PowerFactory, in this case the 33 kV and 11 kV busbars at Meaford C BSP. Line parameters were set in the model by interrogating GIS (geographic information system) data for network assets, which yielded per-section data including conductor type and section length.

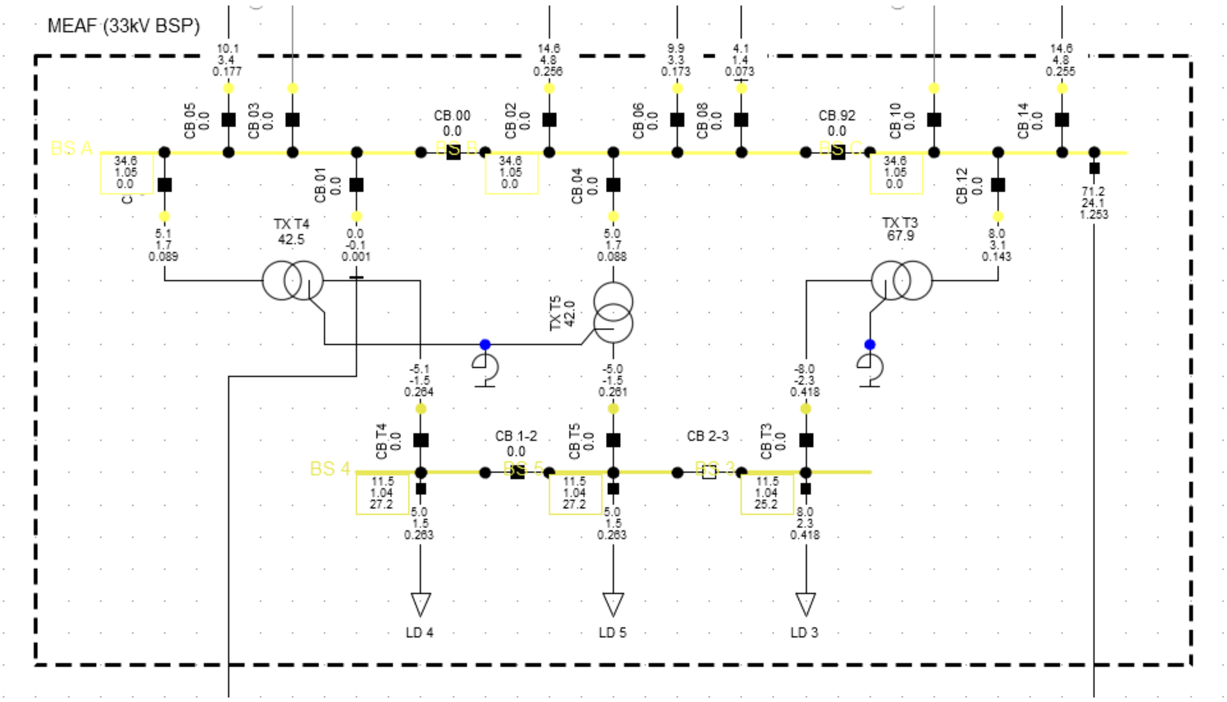

Figure 2-9: A section of the power system model for the Meaford C trial area, showing Meaford C BSP 33 kV elements

Data for LCT harmonic current injections have been obtained from publicly available sources such as the ENA type register and conference publications. These data form the basis of the LCT models to be used in the studies during the Trial phase of the project.

This activity in the Build phase of the project is now complete.

2.5 Phase 3: Trial

The Trial phase includes several activities that utilise the systems developed and deployed during the Build phase, including analysis of PQ data from the PQ monitor trial, trials of the PQ analysis automation software, power system studies, and follow-up VT testing.

2.5.1 PQ Monitor Trial Data Analysis

This activity is concerned with analysing the PQ data collected by the monitors installed during the Build phase of the project.

Progress within this reporting period

During the present reporting period, a document has been prepared and agreed that defines the scope of the PQ monitor trial data analysis within the project. The scope is framed by four questions, which are derived from the project's registration document:

1. What PQ impacts are LCTs having on networks?
2. Are week-long snapshots sufficient to capture representative PQ data?
3. Do multiple monitors in a network area deliver useful extra visibility?
4. How do the different PQ monitors compare?

The methods and tools for answering these questions have been set out in the scoping document and will be developed and applied over the coming months.

In addition to setting the scope of the PQ data analysis for the remainder of the project, some initial analysis of the trial data from the first months of PQ monitoring across all sites has been undertaken.

The subsequent figures summarise voltage harmonics across several 33 kV sites for the 6 week period 23rd December 2019 to 2nd February 2020: Figure 2-10 is for 5 sites within the Meaford C (low LCT) area; Figure 2-1 and Figure 2-12 are for sites fed from GT1A and GT1B, respectively, within the Ryeford (high LCT) area; and Figure 2-23 compares data from 3 BSPs monitored as part of the project (note, Ryeford BSP is normally run split at 33 kV). For each harmonic order at a site, the 95th percentile value of the L1-L2 harmonic voltage data from the 6 week period is presented, with the y-axis scale being the percentage of the ER G5/4 planning limit for each harmonic order.

The sites in the high LCT area fed by Ryeford GT1B (Figure 2-12) exhibit significant differences in the voltage harmonic magnitudes. For instance, the aggregate of the 15th harmonic varies between 11.85% (Coaley) and 45.60% (Solar #3 site), whilst the 21st is as high as 52.94% (Solar #1) and as low as 16.05% (at Ryeford BSP). This is an early indication that monitoring of remote nodes is needed in order to give full visibility of PQ across a network area.

In the low LCT area fed by Meaford C (Figure 2-10), there is some variation in the harmonic aggregate values across the sites; however, the variations are smaller in magnitude than for the high LCT area fed by Ryeford GT1B. Some are the largest differences are for the 5th harmonic (from 57.73% at Market Drayton up to 78.19% at Meaford C BSP) and the 15th (from 2.29% at Meaford C BSP up to 18.70% at Hookgate). There is a similar limited amount of variation across the sites fed by Ryeford GT1A (Figure 2-1), which is separate at 33 kV to the GT1B side and does not feature any LCTs at 33 kV.

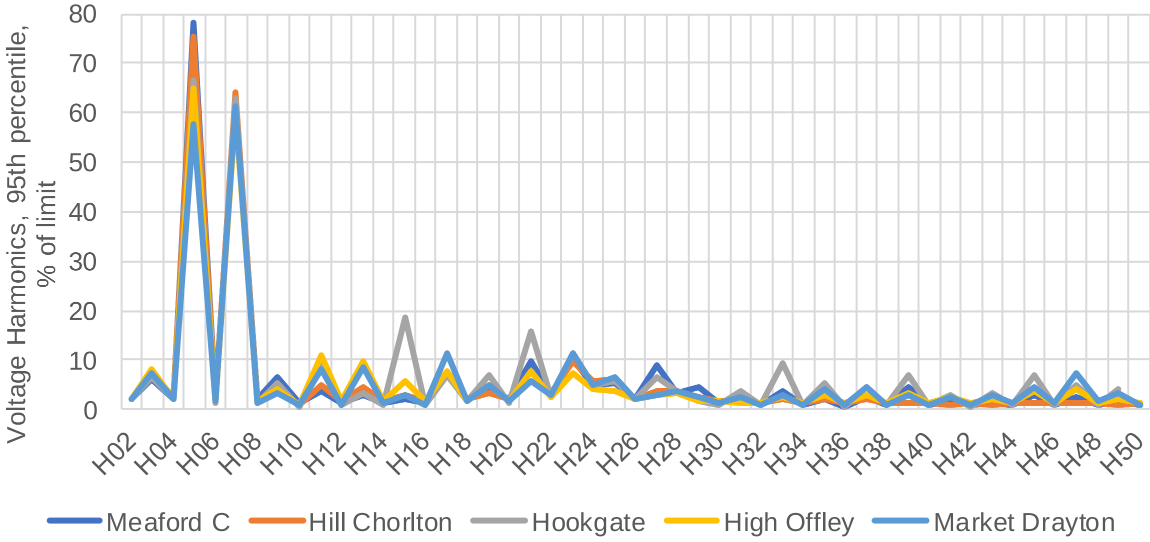

Figure 2-10: Summary of voltage harmonics across the Meaford C trial area, 23 Dec 2019 – 2 Feb 2020

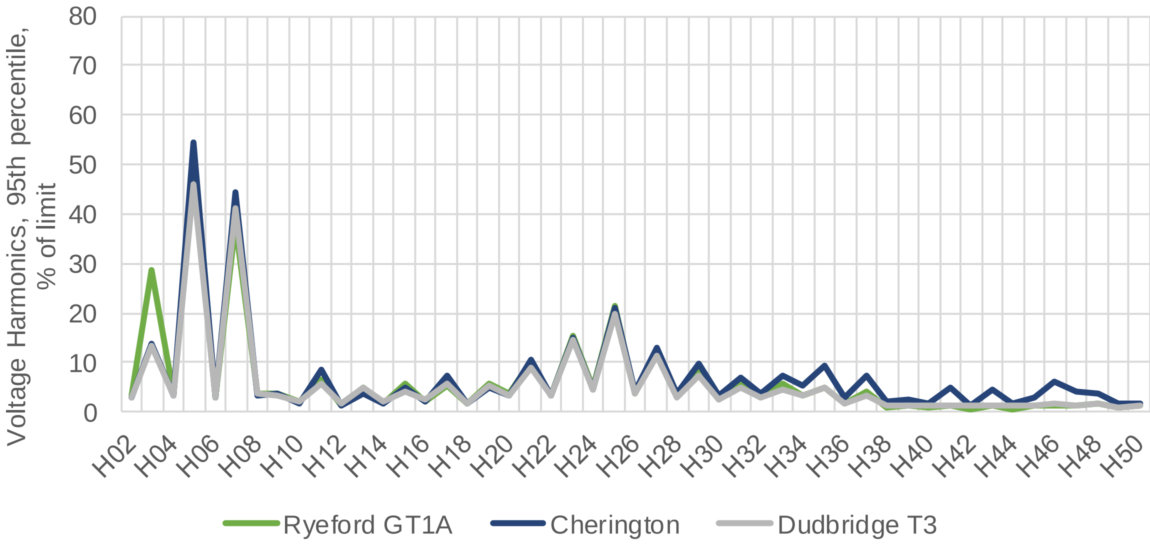

Figure 2-11: Summary of voltage harmonics across the Ryeford (GT1A) trial area, 23 Dec 2019 – 2 Feb 2020

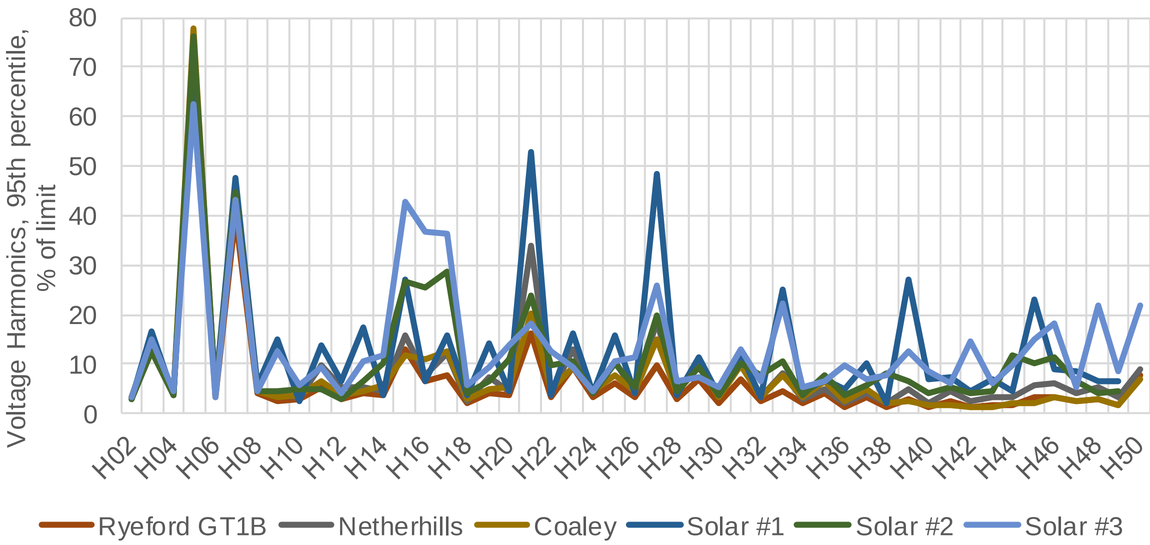

Figure 2-12: Summary of voltage harmonics across the Ryeford (GT1B) trial area, 23 Dec 2019 – 2 Feb 2020

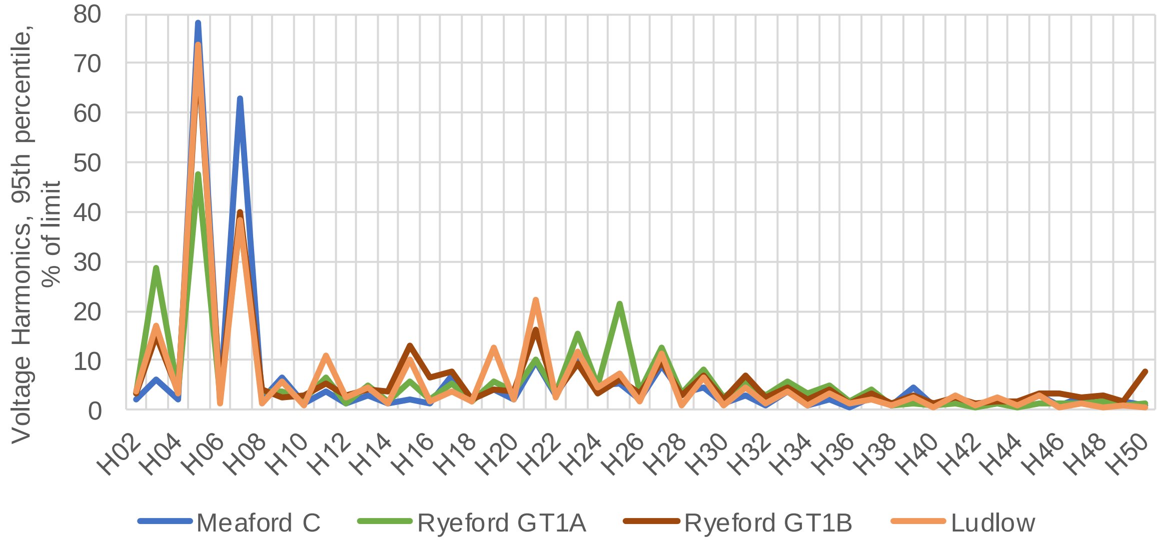

Figure 2-23: Summary of voltage harmonics across monitored 132/33 kV BSPs, 23 Dec 2019 – 2 Feb 2020

This activity will continue into the next reporting period and beyond.

2.5.2 PQ Analysis Automation Software

During the Trial phase of the project, this activity involves WPD staff trialling the PQ analysis automation software features that have been developed during the Build phase.

Progress within this reporting period

A limited number of WPD staff have been trialling the software features as they have been released. A PQ working group is in the early stages of being set up to trial the features more extensively, and this will be running in the next reporting period.

2.5.3 Modelling & Studies

This activity follows on from the construction of power system and LCT models during the Build phase, and uses the models and data collected from the project to perform future-looking power system studies to help understand the future PQ impacts of LCTs.

Progress within this reporting period

The majority of the work for this activity will be in the next reporting period; however, some progress has been made in the present reporting period in setting up and tweaking the models in readiness for studies.

2.5.4 Follow-up VT Testing at NPL

The VT testing during the Design phase found that VTs may significantly attenuate higher-order harmonics between their inputs and outputs. Due to the potential significance of the findings, a separate laboratory (the National Physical Laboratory, NPL) have been engaged to perform follow-up VT testing to confirm the results. This follow-up testing also adds some additional useful features that enhance the potential learning for the project, including testing the influence of other factors such as the burden on the VT secondary circuits and the type of wiring used.

Progress within this reporting period

During the present reporting period, the scope of the testing to be performed by NPL has been agreed and a contract put in place for delivery. A kick-off meeting with NPL is scheduled early in the next reporting period, and the testing should take place throughout the next reporting period.

2.6 Phase 4: Report

The Report phase is the last phase of the project and includes developing policies for Business-as-Usual (BaU) adoption of the project's findings, dissemination of findings through events, and preparation of the close-down report. Only progress on the policies have been made, so only that activity is reported on below.

2.6.1 Policies for Business-as-Usual Adoption

This activity involves drafting WPD policies to allow the project's methods and findings to be adopted in BaU operations. Two policies are planned to be developed: 1) a Standard Technique on PQ monitor installations, and 2) a Standard Technique on PQ data analysis.

Progress within this reporting period

A Standard Technique on PQ monitor installations has been drafted.

2.7 Next Steps

The activities described below are planned for the next reporting period, which is in phase 3 (Trial) of the project. Phase 4 (Report) will run concurrently, whilst the software development activity of phase 2 (Build) will continue into the next reporting period.

The PQ monitor trial will continue throughout the next reporting period. Analysis tools will continue to be developed and will be applied to the first sixth months of data to produce an interim data analysis report.

Development of the PQ analysis automation software will continue. The remaining two main features (the events timeline browser element of the PQ Events Viewer and PQ Assessment Tool) will be developed and deployed. The two reporting features that have been recently added to the software scope will be specified and developed. All features will be trialled by WPD staff.

The modelling and studies aspect of PNPQA will continue, with studies using existing PQ data and data from the PQ monitor trials taking place.

The follow-up VT testing at NPL will be kicked off, the testing equipment set up, and some, if not all, of the testing should be completed.

3 Progress Against Budget

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

Table 3-1: Project progress against budget

Spend Area	Budget (£k)	Expected Spend to Date (£k)	Actual Spend to Date (£k)	Variance to Expected (£k)	Variance to expected (%)
Nortech Delivery	635.4	540.6	540.6	0.0	0.0%
WPD Project Management	45.7	29.4	45.2	+15.8	+53.7%
Technology and Installation	553.8	492.7	394.7	-98.0	-19.9%
Contingency	123.6	0.0	0.0	0.0	0.0%
TOTAL	**1358.5**	**1062.7**	**980.6**	**-82.1**	**-7.7%**

WPD Project Management

This spend is higher than expected due to change of project managers early on in the project, extra project management days have been required for the current project manager to be able to deliver this project successfully.

Technology and Installation

This is underspent due to a delay in VT (Voltage Transformer) testing carried out by National Physical Laboratory (NPL), the start of this testing has been delayed due to current UK wide restrictions on travel and work as a result of the COVID-19 pandemic.

4 Progress Towards Success Criteria

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

Table 4-1: Progress towards success criteria

Success Criteria	Progress
Impact of LCTs on power quality and harmonics within primary networks better understood.	• All 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. • Further VT testing to validate the accuracy of equipment used for PQ measurements has been completed at The University of Manchester. • NPL have been engaged to perform follow-up VT testing to validate and extend the findings from the testing done by the UoM. • Power system and LCT models have been constructed, which will be used for future-looking power system studies to better understand the potential future PQ impacts of increasing LCT penetrations. • The scope for PQ monitor data analysis has been defined and some analysis of the initial month of data has been performed.
Power quality monitors installed at trial locations and remote retrieval of data successfully demonstrated.	• All 46 PQ monitors for the project's trial have been installed. • Interfaces for remote retrieval of data from the three types of PQ monitors being used in the trial have been completed, including final testing. • Data has successfully been remotely retrieved from all installed PQ monitors.
Tools for automating power quality data retrieval and analysis demonstrated.	• All six main features of the PQ analysis automation software have been specified. • Four of the six main software features have been developed and deployed to the project's data server. • A key aspect of the fifth main software feature (an events recording viewer) has been developed and deployed to the project's data server.
Policies created to implement project outputs in WPD's business.	• A Standard Technique on PQ monitoring installs has been drafted.

5 Learning Outcomes

The learning across different areas of Phases 1 (Design), 2 (Build), and 3 (Trial) 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 50th) but introduce attenuation in the output magnitude at higher frequencies.

- **PQ monitor installations**

Installation of a plug & play PQ monitor with voltage and current (clamp CT) inputs takes between 1-2 hours with 2-3 personnel, including sourcing power and post-install checks. There is no significant time saving if current monitoring is skipped.

- **PQ impacts of LCTs**

Initial analysis of the PQ data collected so far indicates there are significant variations in harmonic levels across network areas featuring LCTs.

6 Intellectual Property Rights

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

- Methodology and results of VT harmonic response testing;
- Development and application of a methodology for trial area and site selection;
- Implementation of interfaces for retrieving PQ data off PQ monitors;
- Requirements and designs for PQ analysis automation software; and
- 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 20 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.

Table 7-1: Summary of top five current risks (by rating)

Details of the Risk	Risk Rating	Mitigation Action Plan	Progress
Nortech resources are unavailable	Moderate	1. Follow government COVID-19 advice and Nortech policy (working from home, avoid physical meetings) 2. Nortech to assign dedicated resources 3. Stand-in resources to be identified to cover staff absences 4. Re-arrange programme around staff availability	Nortech staff working from home and only visiting the office if essential (e.g. to do hardware testing or configuration)
WPD resources are unavailable	Moderate	1. Follow government COVID-19 and WPD advice (e.g. working from home, avoid physical meetings, etc.) 2. Close working relationship between WPD and Nortech 3. Nortech empowered to contact alternative WPD staff for assistance	WPD PM working from home
Nortech does not deliver required performance	Moderate	Nortech appointed based on past record	-
Delays in VT testing	Minor	1. Plan in for delays, 2-3 months slack available	PO raised with NPL; NPL programme has 2-3 months

Details of the Risk	Risk Rating	Mitigation Action Plan	Progress
		2. Regular updates with NPL	slack at end to stay within overall project end date
Quality of VT testing insufficent	Minor	1. Clearly define and agree testing deliverables 2. Witness testing 3. Regular calls to track progress / issues	NPL kick off meeting being arranged

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

Table 7-2: Graphical view of Risk Register

Likelihood = Probability x Proximity						
	Certain/Imminent (21-25)	0	0	0	0	0
	More likely to occur than not/Likely to be near future (16-20)	0	0	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	1	2	0	0
	Very unlikely to occur/Far in the future (1-5)	1	7	8	1	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	**17**	**3**	**0**	**0**	**No of instances**
Total	**20**				No of live risks

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

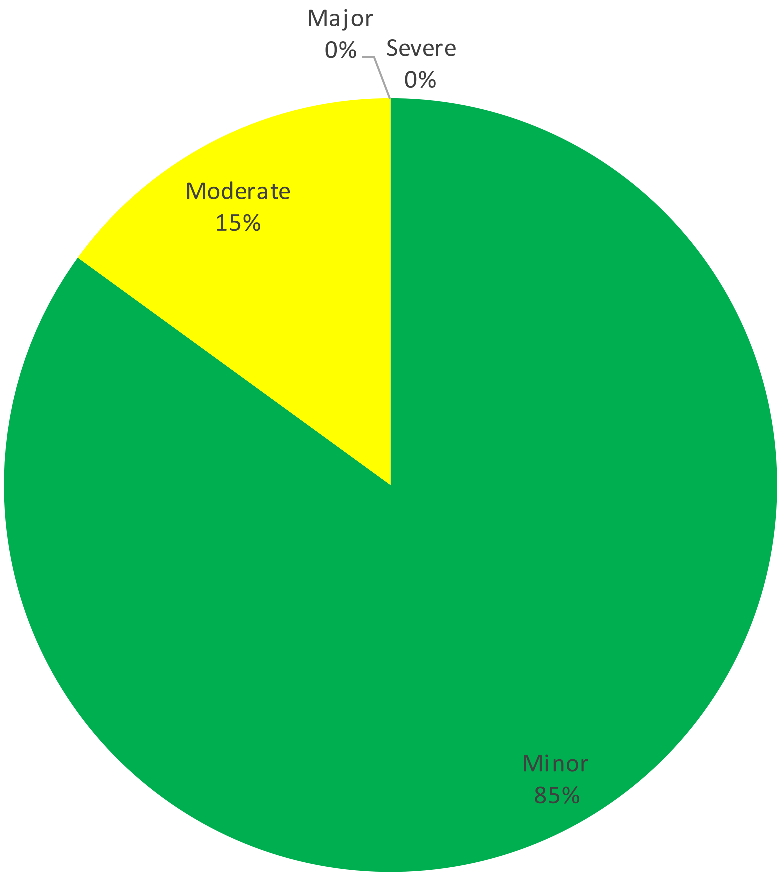

Figure 7-1: Percentage of risks by category

8 Consistency with Project Registration

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

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
BaU	Business-as-Usual
BSP	Bulk Supply Point
CT	Current Transformer
DAQ	Data Acquisition
EV	Electric Vehicle
GIS	Geographic Information Systems
IPR	Intellectual Property Rights
LCT	Low Carbon Technology
NIA	Network Innovation Allowance
NPL	National Physical Laboratory
PNPQA	Primary Networks Power Quality Analysis
VT	Voltage Transformer
UoM	University of Manchester
WPD	Western Power Distribution

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