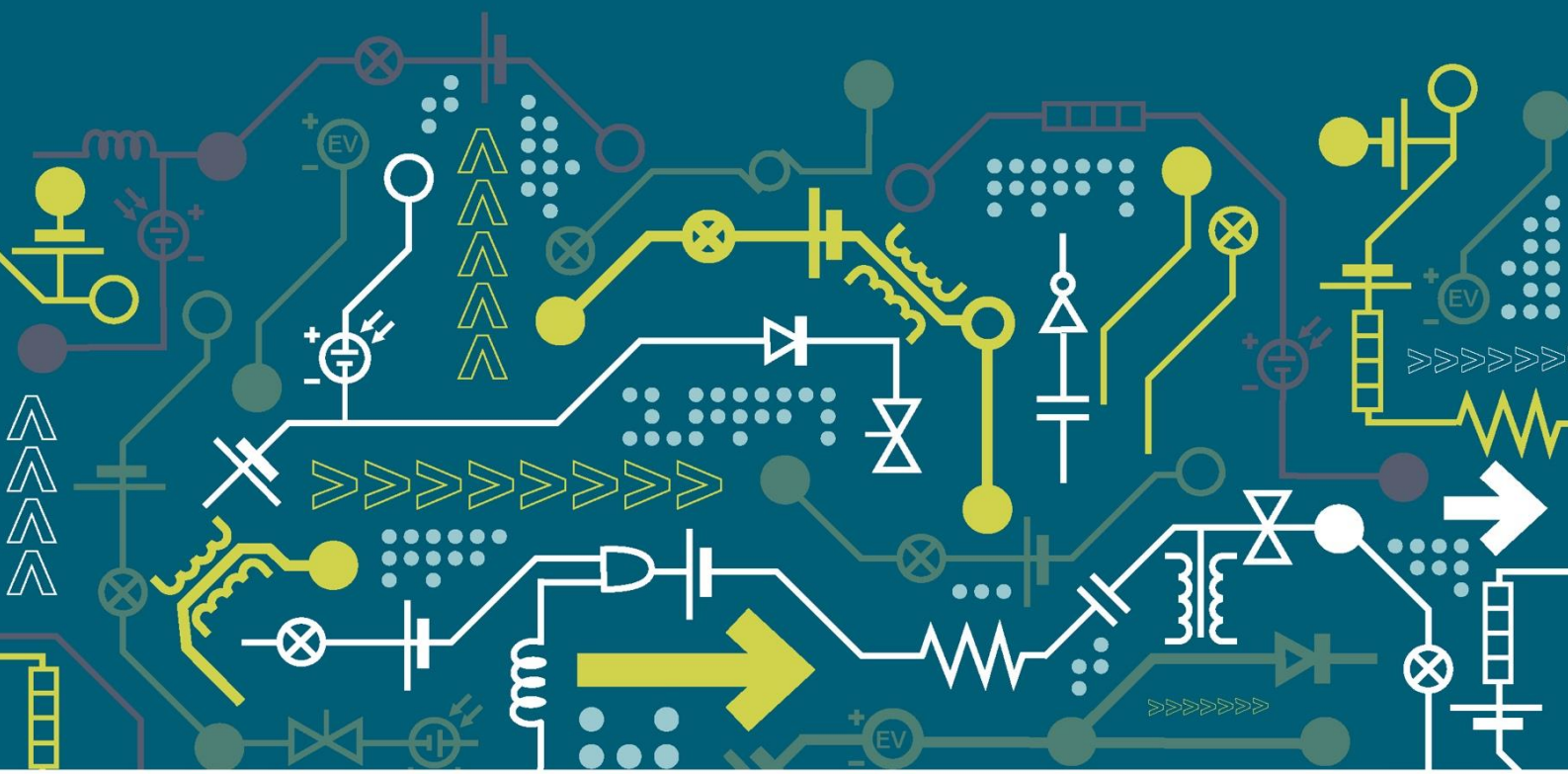
WPD INNOVATION

Primary Networks Power Quality Analysis

NIA Major Projects Progress Report

March 2020 – September 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 in February 2021.

The project budget is £1,358,400 of which £1,222,560 has come from the Network Innovation Allowance (NIA) funding.

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 2020 to September 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 117 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, We are 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 fifth progress report, covering progress from the start of April 2020 to the end of September 2020.

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

[1] National Grid, Future Energy Scenarios (2020 and 2017): http://fes.nationalgrid.com/
[2] https://www.gov.uk/government/publications/clean-growth-strategy

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;
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; and
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 (October 2019 to March 2020), the project's installation of 46 PQ monitors was completed, allowing the PQ monitor trial to be fully underway. The scope of analysing the monitored PQ data was defined and some initial analysis undertaken. The PQ analysis automation software development was progressed, with all functional specifications completed for the six main features, and a key element of the fifth main feature was developed. Power system and LCT models were constructed for future-looking power system studies of the potential PQ impacts of increased LCTs. The University of Manchester (UoM) completed re-testing the harmonic performance of Voltage Transformers (VTs) using new measurement equipment, following on from the tests during previous reporting periods. A second laboratory, the National Physical Laboratory (NPL) was engaged to perform follow-on testing to confirm and extend the results gained so far.

Progress has been made during the present reporting period although some elements have been affected by measures put in place in response to the COVID-19 pandemic.

The final features of the PQ analysis automation software have been completed: 1) the PQ events timeline browser element of the PQ Events Viewer, and 2) the PQ Assessment Tool, which performs an ER G5/5 Stage 2C connection assessment. Two additional reports relating to PQ data have been developed. Some of the features developed during previous reporting periods have been enhanced based on user feedback from Simon Scarbro

The communicating PQ monitor trial has continued alongside analysis of the data. The main focus of the analysis task during the present reporting period has been in developing tools to assist the analysis of the data, which shall be used to generate outputs to be included in the project's data analysis report.

The network models developed during the previous reporting period have been updated to improve their fidelity, including a more detailed representation of network areas electrically adjacent to the trial areas that were already modelled in detail.

The start of the follow-up VT harmonic testing at NPL has been delayed significantly due to partial site closures and restrictions on transporting equipment such as the VTs from the UoM to NPL; however, all equipment has been delivered and laboratory work is now underway and will be completed in March 2021.

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 for Nortech)
    - Simon Hodgson (Technical Manager for Nortech)

1.4 Procurement

Table 1-1 below details the current status of procurement for this project. Only two items remain active with some delivery remaining, and these have been highlighted in **bold**.

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 – February 2021**
(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:

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 second phase included 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;
3. 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; additionally, this phase also includes follow-up VT harmonic testing; 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 third phase (Trial), with a single activity from the second phase (Build) completing during the reporting period. The following progress has been made:

- Power quality data has continued to be received from the 46 communicating power quality monitors installed during previous reporting periods;
- Software to automate retrieval and analysis of PQ data has been completed;
- Analysis of the first 6 months of monitoring data from all sites is underway;
- The power system models for future-looking power system studies of the potential PQ impacts of increased LCTs have been enhanced to increase modelling fidelity, and initial power system studies are underway; and
- Follow-up VT testing at NPL has been kicked off, to validate and extend the earlier testing done by the UoM.

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.

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 previous reporting period, except PQ analysis automation software development, which continued into the present reporting period and is therefore the only activity reported on below.

2.4.1 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 into 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 from COMTRADE files.
6. PQ Assessment: A tool to perform ER G5/5 harmonic connection assessments using data gathered from PQ monitors.

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

Development of the PQ Events Viewer began during the previous reporting period and included the completion of the events recording viewer element. The second and final element of the feature, the events timeline browser, was developed and deployed during the present reporting period. The event timeline browser provides an alternative to a conventional event list for viewing the history of events across multiple monitoring locations. Figure 2-1 is an example view from the timeline browser, which is a matrix representing monitors (and groups of monitors) from top-to-bottom and time from left-to-right. Each cell in the matrix is the intersection of a monitor (or group) and a particular time span; if there are events for that monitor and time span, then the cell is coloured accordingly. For instance, in the Figure, the time span from 15:00 to 18:00 on the 8th September is selected for the Market Drayton PQ monitor. Selecting that cell will bring up a list of events and event recordings that match that location and time, such as what is shown in Figure 2-2.

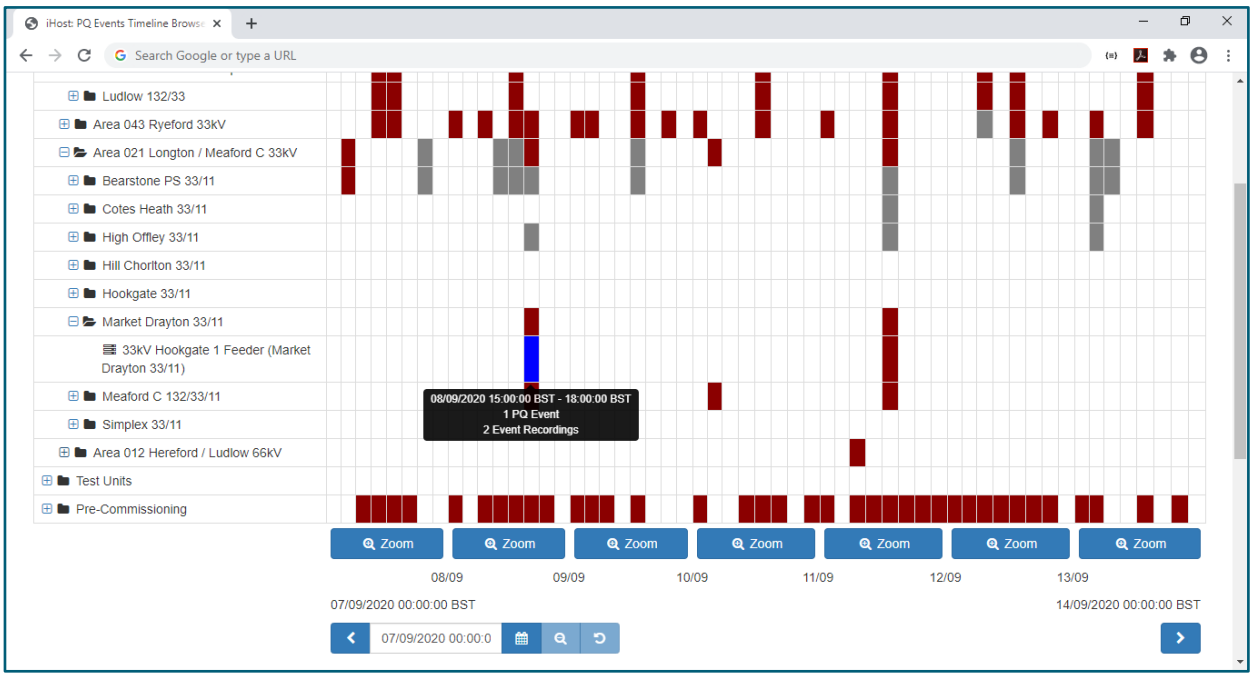

Figure 2-1: Event Timeline Browser view of events recorded during the week commencing 7th September 2020

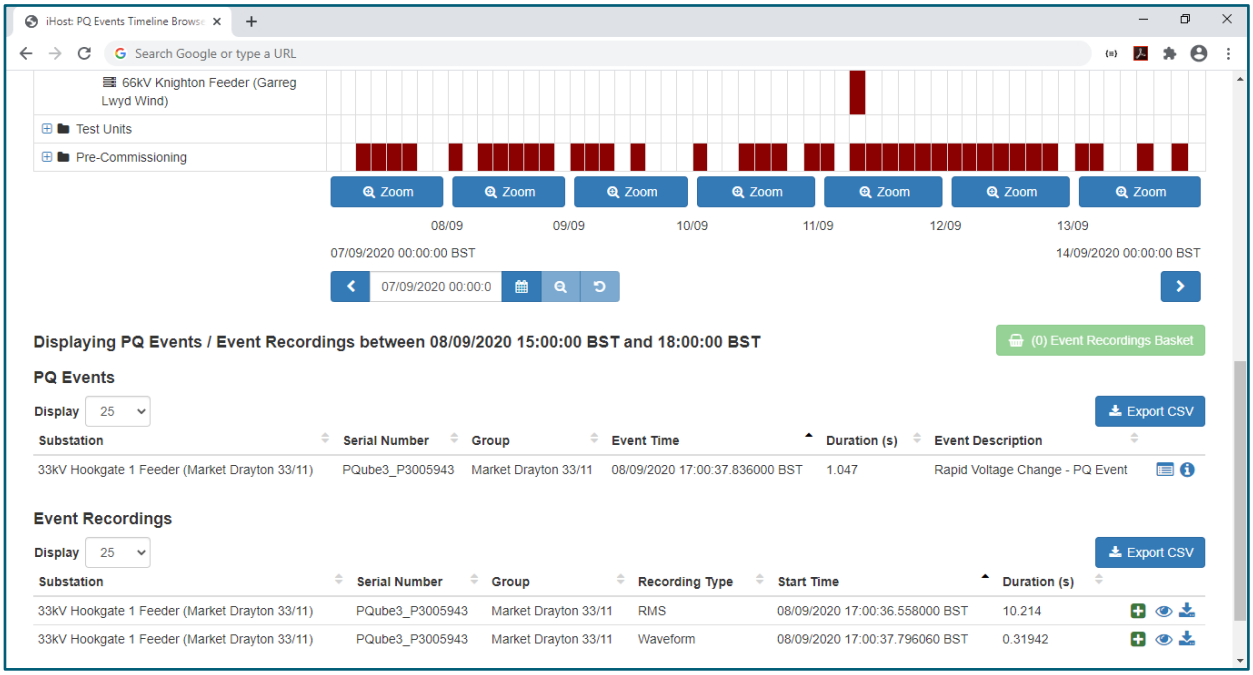

Figure 2-2: Events and event recordings list within the event timeline browser for a selected monitor and time span

The sixth main feature software, the PQ Assessment Tool, was specified during the previous reporting period and has now been developed and deployed. The PQ Assessment Tool allows a user to perform an ER G5/5 Stage 2C power quality assessment within the iHost software environment, without using external tools, which is an important stage in evaluating some customer connection requests. A user can customise a run of the PQ Assessment Tool within iHost (an example of this is shown in Figure 2-3), and then generate a report in Microsoft Excel workbook (*.xlsx) and Adobe Acrobat document (*.pdf) formats (an example of a PDF report is shown in Figure 2-4).

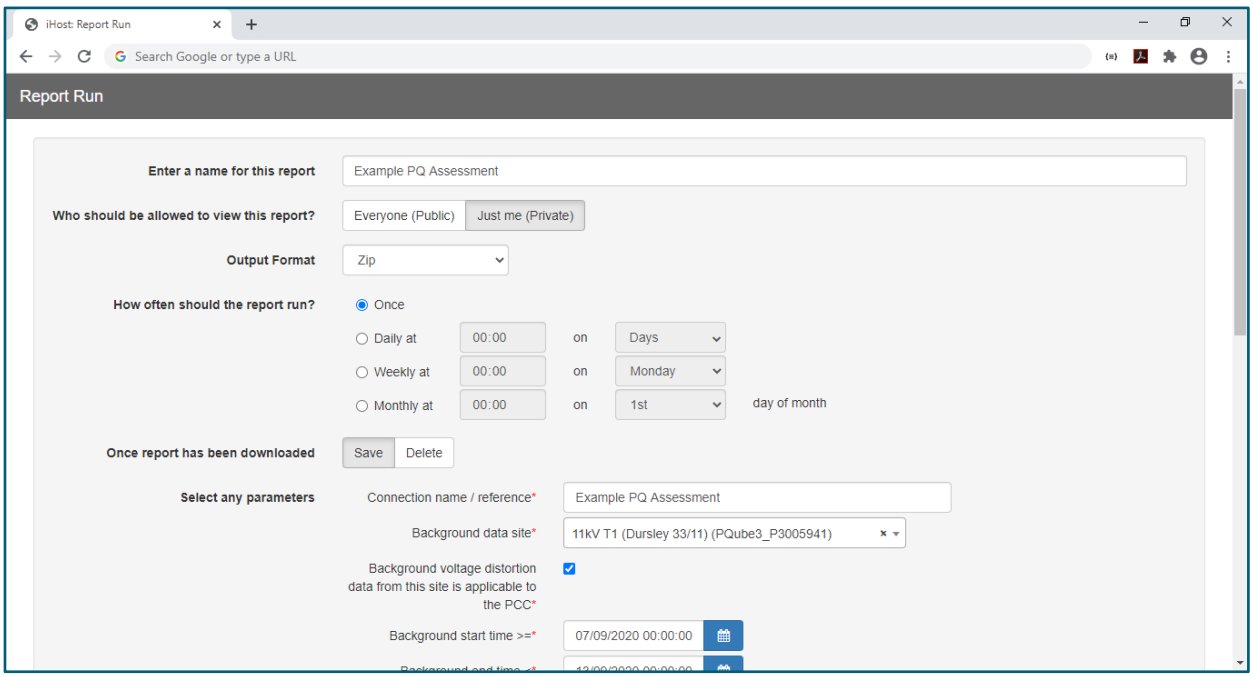

Figure 2-3: PQ Assessment Tool set up page

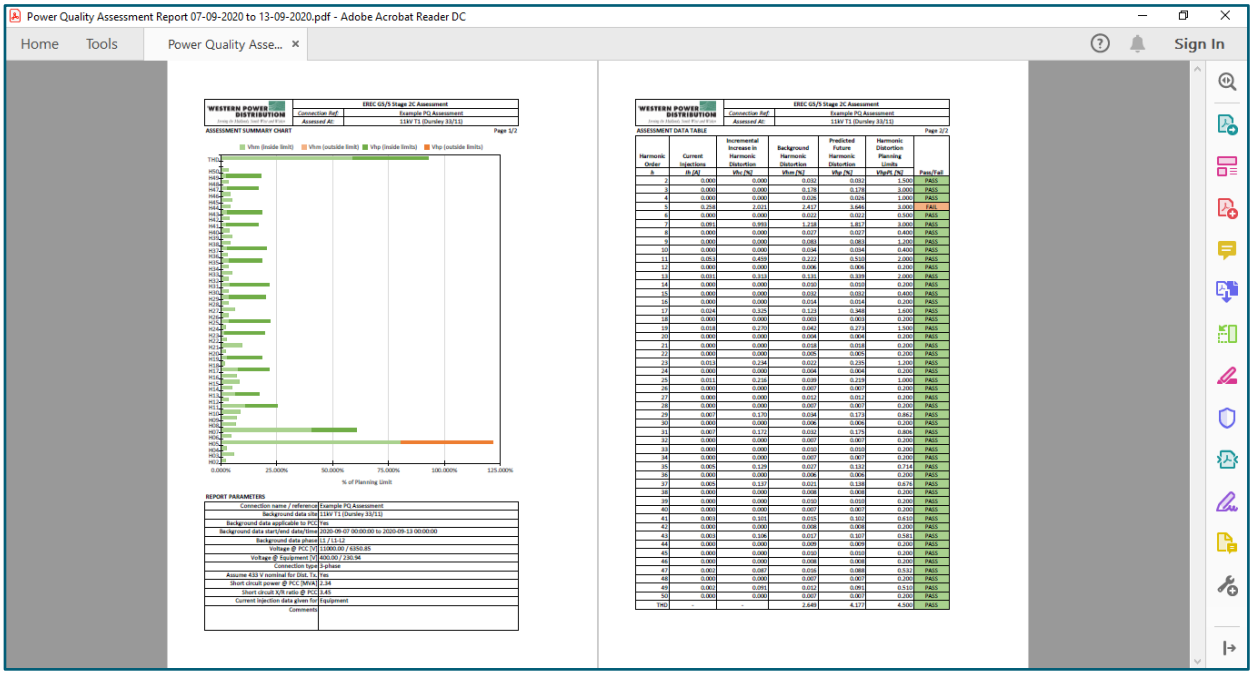

Figure 2-4: Example PDF report generated by the PQ Assessment Tool

In the previous reporting period two additional reporting features were added into the scope of the software: 1) an EN 50160 report, and 2) an ER G5/5 background data report. Both of these reports were specified, developed, and deployed during the present reporting period.

This activity has now concluded.

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

The focus of the analysis activity over the present reporting period has been building tools to handle and analyse the large amounts of data that is being collected through the PQ monitor trial, so that the outputs of the analysis can be included in the project's data analysis report.

The functionality of the analysis tools includes extracting data from the online iHost monitoring database and storing the data in offline archives, in order to speed up the analysis by removing the need for repeated large data requests over the internet. The project is using Hierarchical Data Format (HDF) for the offline data archives. HDF is typically used for transferring large scientific datasets and offers a number of benefits over other file formats that are often used such as CSV (Comma-Separated Values) band JSON (JavaScript Object Notation). One major benefit is that numeric data is stored directly as numeric data, rather than being encoded as text, which significantly reduces the storage space requirements. Another key benefit is the hierarchical structure of a HDF file allows multiple datasets to be stored in the same file and retrieved separately, rather than requiring the whole file to be read in to memory, reducing access time and memory requirements.

Another aspect of the tools being developed to assist the analysis is development of Python scripts to automate the processing of data from the HDF data archives, calculate various statistics, and produce charts of the data (such as the box plot of voltage harmonics in Figure 2-5) for inclusion in the data analysis report that is being developed for the project.

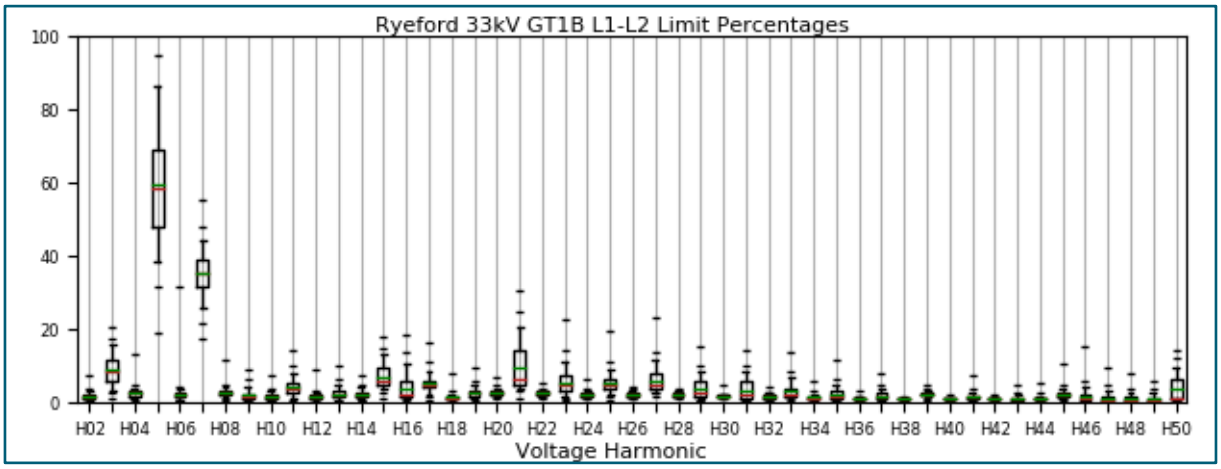

Figure 2-5: Box plot of the distribution of voltage harmonic values (% of planning limit) for Ryeford GT1B from 7th October 2019 to 2nd August 2020

The analysis of data collected so far in 2020 has revealed some changes in PQ due to the COVID-19 pandemic response. National Grid has reported that demand fell by up to 20% during lockdown[3] and changes of that magnitude have been seen at some of the project's trial sites. For example, Figure 2-6 shows the mean daily real power measured at two trial sites, Meaford C 33 kV BSP and Cherington 33 kV Primary (which is fed by Ryeford BSP), relative to the mean real power for January and February. It is clear to see that there is a significant (up to 40%) and sharp drop in power (demand) during March, followed by a slow rise, up to the present date. At the start of the lockdown period there is also a lessening of the differentiation between weekday and weekend demand (weekend demand is typically lower) as energy usage behaviour changes.

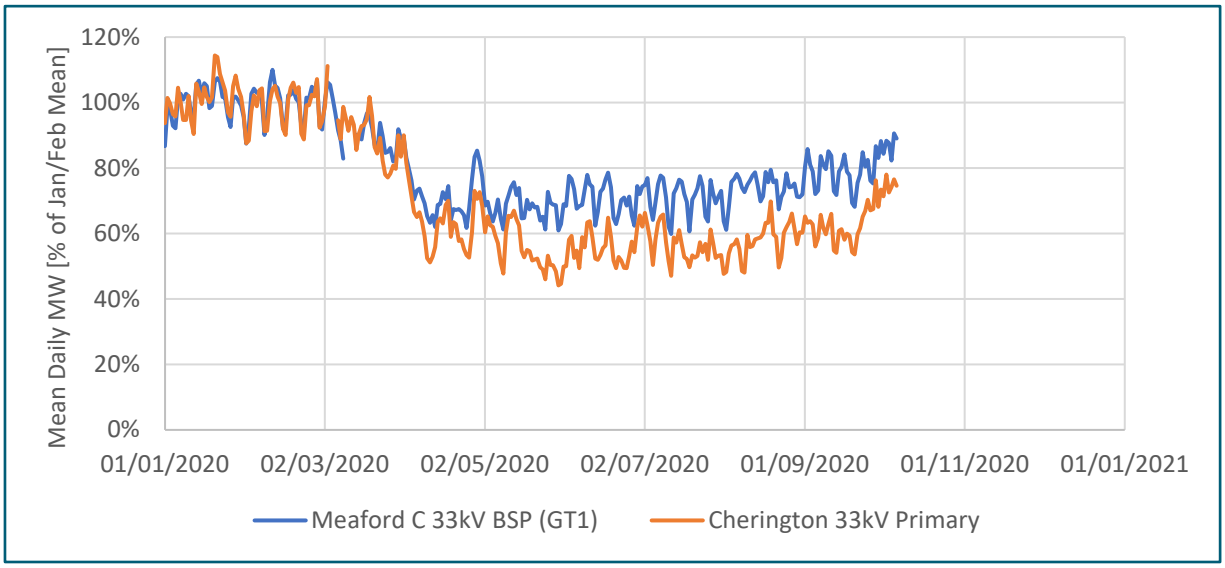

Figure 2-6: Mean daily real power for 2020 to date at Meaford C BSP and Cherington 33 kV Primary

[3] 4 ways lockdown life affected UK electricity use | National Grid Group https://www.nationalgrid.com/uk/stories/grid-at-work-stories/4-ways-lockdown-life-affected-uk-electricity-use

Coincident with the decrease in demand has been an increase in voltage THD, one reason this could be is that demand absorbs harmonics, and the potential increase of harmonics as a result of people working from home and the increase in electronic devices being used where otherwise they wouldn't be. Figure 2-7 shows this for the same two trial sites. For Meaford C BSP, THD rises steadily throughout March, and is sustained at elevated levels until September, when there is a noticeable decrease. At Cherington, there is a sudden rise in THD at the start of lockdown, which is maintained until June, when maintenance activities result in the significant changes in THD seen.

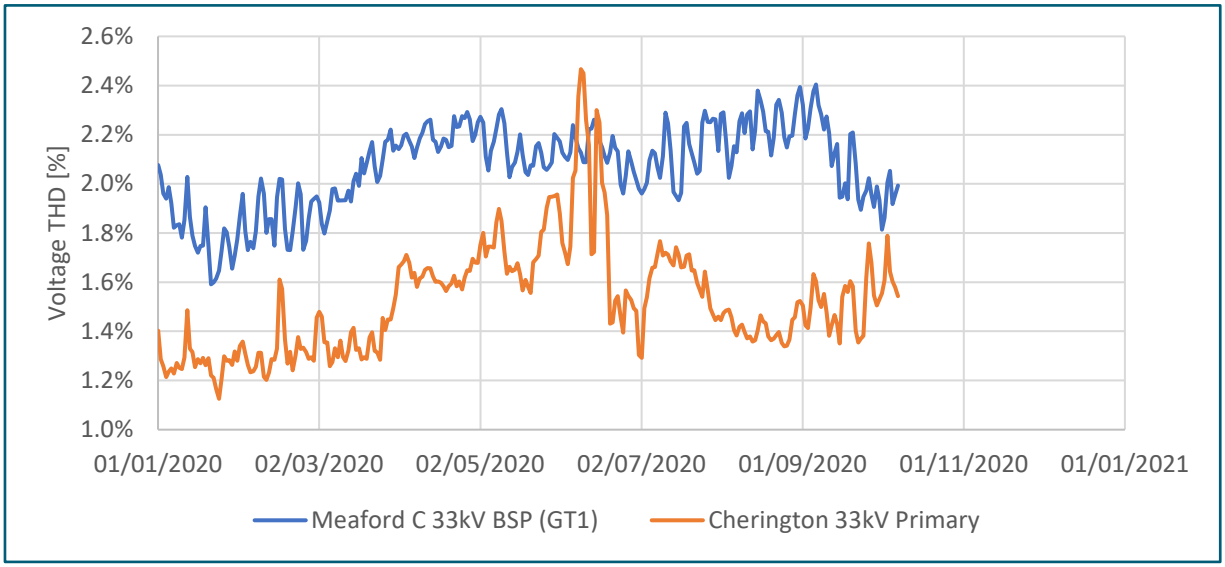

Figure 2-7: Daily voltage THD 95th percentile values for 2020 to date at Meaford C BSP and Cherington 33 kV Primary

The change in demand and coincident changes in PQ due to the COVID-19 response may result in the majority of data collected in 2020 being unrepresentative of usual operating conditions and therefore may be unsuitable for the future-looking power system studies. This is a risk that is being monitored.

This activity will continue into the next reporting period.

2.5.2 PQ Analysis Automation Software

During the Trial phase of the project, this activity involves our (WPD) staff trialling the PQ analysis automation software features that were developed during the Build phase.

Progress within this reporting period

The software features developed during the previous reporting periods have been trialled on an ad hoc basis by Simon Scarbro (WPD Primary System Design) and Nortech staff, and based on the feedback from this testing some of the existing software features have been enhanced during the present reporting period:

- PQ Data Ingest and PQ Trends now support minimum and maximum measurements for selected measurands such as RMS voltage and current. This is useful, for example, when analysing the data to find short duration current spikes and voltage dips indicative of fault activity, such as the plot of RMS current shown in Figure 2-8.
- PQ Heat Maps has been updated with revised colour gradients and an optional legend to make the display more understandable. An example of the updated PQ Heat Maps display is shown in Figure 2-9, which is a heat map of voltage THD (Total Harmonic Distortion) in the Ryeford trial area.

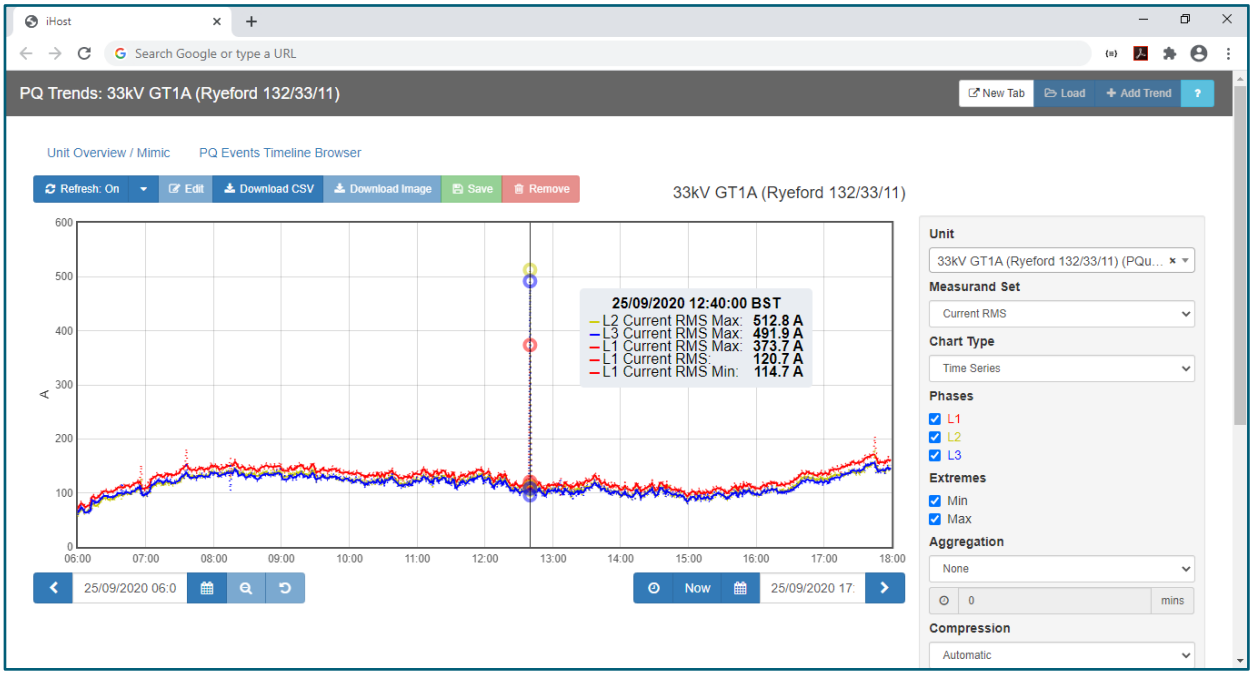

Figure 2-8: Updated PQ Trends with min and max data displayed for RMS current, including a current spike likely due to fault activity

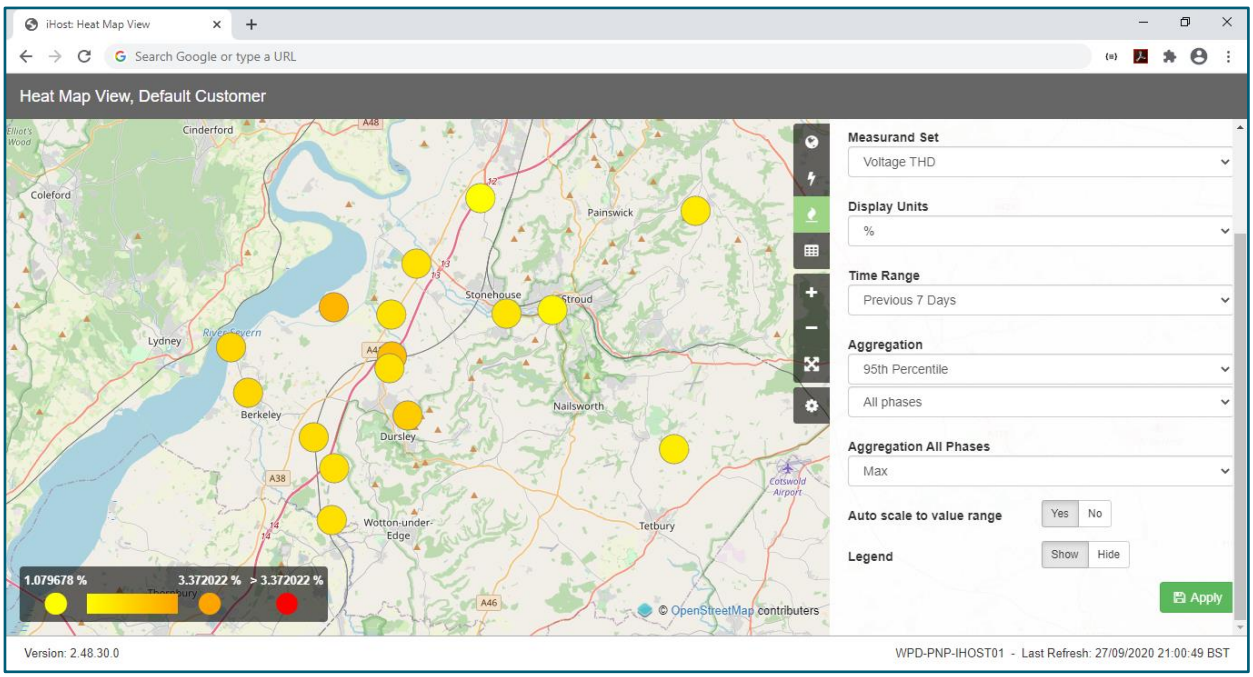

Figure 2-9: PQ Heat Map of voltage THD including updated colour gradients and legend

A PQ working grouphas been set up to trial the features more extensively, they have been given login credentials to allow them access to web iHost and use the software developed, the goal is to feedback relevant information and possible improvements..

This activity has begun and will continue into 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

This activity has progressed more slowly than planned due to working adjustments in response to the COVID-19 pandemic. The network models developed during the previous reporting period have been updated to improve their fidelity, including a more detailed representation of network areas electrically adjacent to the trial areas that were already modelled in detail. Initial studies have started on the base case models, with harmonic impedance loci being calculated. The models are nodal network models of the two trial areas. They feature the 33kV primary network of the trial areas and the upstream 132kV network up to the GSP bars. The models were built in DIgSILENT PowerFactory from a mix of data sources: EMU (GIS) data for line conductor type and length data, the existing IPSA models for transformer data and NER data (with some cross checking to site records).

This activity will continue into the next reporting period.

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 (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

The VT testing project with NPL was kicked off at the start of the reporting period; however, the COVID-19 pandemic has significantly delayed the start of testing due to the temporary closure of the NPL laboratories to non-essential work and the temporary closure of the UoM, from where several VTs needed to be retrieved and sent to NPL for testing. All test articles have now been delivered to NPL, who have started the laboratory work including calibration of measurement equipment. The burden testing report is due by end of December and all testing completed by end of March 2021.

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.

2.6.1 Policies for Business-as-Usual Adoption

This activity involves drafting 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 was drafted during the previous reporting period. A second Standard Technique, on PQ analysis, shall be drafted in the next reporting period.

2.6.2 Dissemination of Findings

This activity involves preparing technical papers, presenting findings at events, and arranging and delivering project-specific dissemination events.

Progress within this reporting period

During the present reporting period, three abstracts have been developed and submitted for the CIRED 2021 conference. If accepted, the abstracts will be developed into full papers during the next reporting period.

Data gathered by the PNPQA project has been shared with members of the Investigation & Modelling of Fast Frequency Phenomena ("F2P") project[4] from National Grid and Brunel University. Of particular interest to the F2P team are the continuously monitored frequency data (at 10 s time resolution) and half-cycle RMS event recordings captured by the PNPQA PQ monitors.

This activity will continue into the next reporting period.

2.6.3 Close Down Report

This activity involves the drafting, review, revision, and release of the project's Closedown Report, and will be progressed during the next reporting period.

2.7 Next Steps

The activities described below are planned for the next reporting period, which is in both phase 3 (Trial) of the project and phase 4 (Report).

The PQ monitor trial will continue into the start of 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, and then to a whole year of data to produce the final data analysis report.

The modelling and studies aspect of PNPQA will continue, with studies using existing PQ data and data from the PQ monitor trials taking place and being completed. A report analysing the findings from the studies will be produced.

The follow-up VT testing at NPL will continue and should be completed.

The project close-down report will be drafted.

[4] https://www.smarternetworks.org/project/nia_ngso0007

3 Progress Against Budget

Table 3-1 Project progress against budget

Spend Area	Budget (£k)	Expected Spend to Date (£k)	Actual Spend to Date (£k)	Variance to Expected (£k)	Variance to expected (%)
Nortech Delivery	635.4	540.6	567.4	+26.8	+4.7%
WPD Project Management	76.5	29.4	49.2	+19.8	+40.2%
Technology and Installation	553.8	492.7	426.5	-66.2	-15.5%
Contingency	123.6	0.0	0.0	0.0	0.0%
TOTAL	**1389.3**	**1062.7**	**1043.1**	**-19.6**	**-1.8%**

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 testing carried out by 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

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.
    - 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 started on 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. Tools for performing the analysis of the large datasets are being developed.
2. 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.
3. Tools for automating power quality data retrieval and analysis demonstrated.
    - All six main features of the PQ analysis automation software have been specified, developed, and deployed to the project's data server.
    - Two additional reporting features (an EN 50160 compliance report and an ER G5/5 background report) have been specified, developed, and deployed.
4. 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 2 (Build) and 3 (Trial) during the current reporting period is summarised below:

- PQ data analysis
    - Using the HDF file format offers several advantages to more commonly used file formats for data storage such as CSV and JSON, including storage and memory savings, and faster data retrieval.

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 our own 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
Further delays in VT testing	Moderate	1. Plan in for delays 2. Regular updates with NPL 3. Add available results to close down report	All equipment delivered to NPL; however, lab work delayed.

Details of the Risk	Risk Rating	Mitigation Action Plan	Progress
Nortech does not deliver required performance	Moderate	Nortech appointed based on past record	-
Trial data affected by COVID-19 response	Minor	1. LCT data may be unaffected (e.g. solar output) 2. Analysis could focus on unaffected periods	-

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	3	0	0
	Very unlikely to occur/Far in the future (1-5)	0	6	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	15	4	0	0	**No of instances**
Total	19				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.

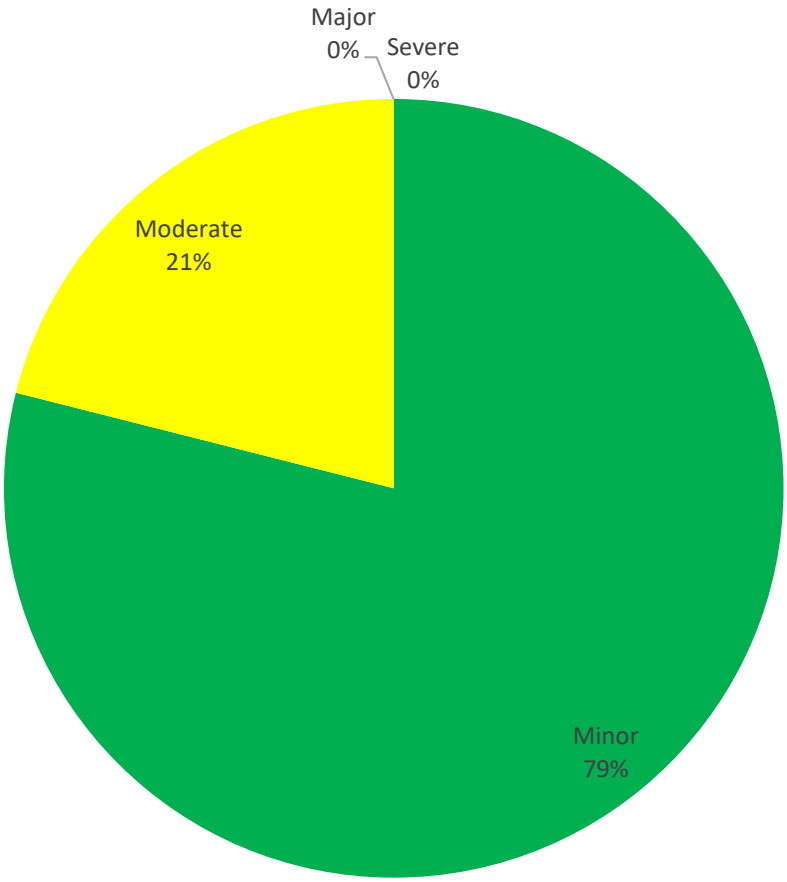

Figure 7-1: Percentage of risks by category

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

This report has been prepared by the PNPQA Project Manager (James King) and by WPD Project Manager (Steven Pinkerton-Clark), reviewed by WPD Innovation Engineer (Chris Harrap) and approved by the WPD Innovation Team Manager (Yiango Mavrocostanti).

All efforts have been made to ensure that the information contained within this report is accurate. We confirm that this report has been produced, reviewed and approved following our quality assurance process for external documents and reports.

Glossary

Term	Definition
BaU	Business-as-Usual
CSV	Comma Separated Values
IPR	Intellectual Property Rights
JSON	JavaScript Object Notation
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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