WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS

PRIMARY NETWORKS POWER QUALITY ANALYSIS

WPD_NIA_028

NIA MAJOR PROJECT PROGRESS REPORT

REPORTING PERIOD:

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Contents

1 Executive Summary

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

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

This report details progress of the project, focusing on the period from registration in March until September 2018.

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 first progress report. It covers progress from initial registration in March 2018 to the end of September 2018.

Nortech Management Ltd. has been 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 current phase of the project, which includes testing the harmonic performance of voltage transformers (VTs), selection of trial areas and sites, specifying PQ monitor interfaces and PQ analysis software;
2. Build – this next phase 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 combines a widescale trial of communicating power quality monitors with software to automate the collection and analysis of PQ data, along with modelling to understand the future impact of increased LCTs on Primary Networks; and
4. Report – this is the final phase of the project, and includes dissemination events and producing the close down report.

Two candidate trial areas have been identified for the widescale trial of communicating PQ monitors. The 33 kV network fed from Meaford C Bulk Supply Point (BSP), located between Stoke-on-Trent, Stafford, and Market Drayton, is the candidate for the area with a low penetration of LCTs, and site surveys have been completed at all 33/11 kV sites in that area. This area will be used as a base-case network. The network fed by Ryeford BSP, centred on Stroud, is the candidate for the high LCT area and site surveys are planned in October. Following the site surveys, the trial area and site selections will be reviewed and then finalised.

PQ monitors are being tested by Nortech in preparation for enabling remote communications and the purchase of up to 40 units for the widescale trial. Two PQ monitors are currently being tested and third will be tested once it is delivered (in October 2018). A pilot trial of a communicating power quality monitor at Meaford C BSP has been completed, and the learning from the pilot is informing other activities in PNPQA.

Meetings with WPD PQ experts have been held to capture requirements for developing software to automate the retrieval and analysis of PQ data. A specification for this software system is being drafted by Nortech and will be finalised in Q4 2018.

The University of Manchester (UoM) has begun testing VTs to understand their influence on harmonic measurements. Three VTs from WPD have been delivered to and tested at the UoM. The results indicate 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. The VTs tested are both switchgear-mounted and pole-mounted types; however, no 33 kV switchgear-mounted VTs could be found within WPD, so units have been ordered from two suppliers for testing in November.

1.3 Project Delivery Structure

1.3.1 Project Review Group

The PNPQA Project Review Group meets on a bi-annual basis. The role of the Project Review Group is to:

- Ensure the project is aligned with organisational strategy;
- Ensure the project makes good use of assets;
- Assist with resolving strategic level issues and risks;
- Approve or reject changes to the project with a high impact on timelines and budget;
- Assess project progress and report on project to senior management and higher authorities;
- Provide advice and guidance on business issues facing the project;
- Use influence and authority to assist the project in achieving its outcomes;
- Review and approve final project deliverables; and
- Perform reviews at agreed stage boundaries.

1.3.2 Project Resource

WPD: Jonathan Berry (Project Manager for WPD)

Nortech Management Ltd: Project Partner, responsible for day-to-day project management and delivery of the project:

- Samuel Jupe (Project Executive for Nortech)
- James King (Project Manager for Nortech)
- Sid Hoda (Software Development Manager)
- Simon Hodgson (Technical Manager)

1.4 Procurement

The following table details the current status of procurement for this project.

Table 1-1: Procurement Details

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 – November 2018
(undisclosed)	33 kV 1-phase VT	VT testing	October 2018
(undisclosed)	33 kV 1-phase VT	VT testing	October 2018
(undisclosed)	Demo PQ monitor	PQ monitor trials	Delivered July 2018
(undisclosed)	Demo PQ monitor	PQ monitor trials	Delivered July 2018
(undisclosed)	Demo PQ monitor	PQ monitor trials	October 2018

1.5 Project Risks

A proactive role in ensuring effective risk management for PNPQA is taken. This ensures that processes have been put in place to review whether risks still exist, whether new risks have arisen, whether the likelihood and impact of risks have changed, reporting of significant changes that will affect risk priorities and deliver assurance of the effectiveness of control.

Contained within Section 7.1 of this report are the current top risks associated with successfully delivering PNPQA as captured in our Risk Register.

1.6 Project Learning and Dissemination

Project lessons learned and what worked well are captured throughout the project lifecycle. These are captured through a series of on-going reviews with stakeholders and project team members, and will be shared in lessons learned workshops at the end of the project. These are reported in Section 5 of this report.

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

2 Project Manager's Report

2.1 Project Background

PNPQA is split in to four phases:

1. Design – this is the current phase of the project, which includes testing the harmonic performance of VTs, selection of trial areas and sites, specifying PQ monitor interfaces and PQ analysis software;
2. Build – this next phase 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 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 first phase (Design). This phase is progressing on track to meet the key dates to lead on to the next phase (Build), with the following progress made:

- A pilot trial of a communicating PQ monitor at a 33 kV BSP has been completed.
- Testing the harmonic performance of VTs is underway at The University of Manchester, with several 11 kV and 33 kV VTs being sourced from within WPD for testing, and the first round of testing being substantially complete;
- The selection of two trial areas for the widescale trial of communicating PQ monitors is has been progressed, with a selection methodology developed and used to identify two candidate areas (Ryeford and Meaford C), and site surveys completed for one area;
- Several PQ monitors are being bench tested by Nortech, to understand what interfaces can be used for enabling remote communication of PQ data; and
- Meetings with WPD PQ experts have been held to capture requirements for developing software to automate the retrieval and analysis of PQ data.

More detail of the progress within each of these activity areas for phase 1 is provided in the subsections within section 2.3 below. There is no progress to report for the subsequent phases (2, 3, and 4) as they will start in future reporting periods. Next steps for within the next reporting period are described in section 2.4.

2.3 Phase 1: Design

The Design phase includes several activities that run from the start of the project until the subsequent Build phase is underway, which will be during the next reporting period. Progress within each of these activities is described in the following subsections including progress and next steps.

2.3.1 Monitoring Pilot

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

Progress within this reporting period

An Outram PM7000 PQ monitor was installed at Meaford C substation in June 2018. The installation is shown in Figure 2-1. Voltage and current measurement connections were made in to the indoor 33 kV switchgear, and the PQ monitor was connected to a Nortech Envoy communication hub to provide remote data access over the mobile telephone network.

Figure 2-1 – Pilot PQ monitor installation at Meaford C. From left to right: connections in to VT secondary wiring; current clamps around CT secondary wiring; Envoy communications hub and PM7000 PQ monitor installed on top of switchgear.

The Envoy communications hub regularly collects data from the PQ monitor and transmits the data to Nortech's iHost web-based control and monitoring platform, which at present allows measurements to be viewed online and downloaded in bulk for offline analysis. Figure 2-2 shows an example display of voltage data on iHost for a week-long period, with new data samples taken every 10 minutes.

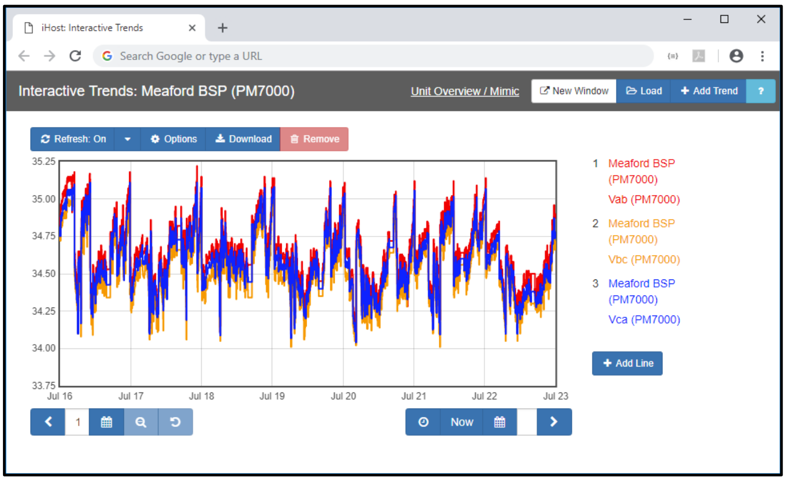


Figure 2-2 – Monitored voltage profiles for an example week viewed on iHost.

Harmonic data collected during the pilot trial has revealed some interesting trends. For example, how harmonics vary across a week, shown for an example week in Figure 2-3. The variation across the week is particularly apparent for the 5th harmonic order. Further analysis has revealed the 5th harmonic is negatively correlated with the substation loading, particularly the reactive power flow. At times of high loading, the 5th harmonic is suppressed, whereas during low loading (evenings and weekends) the magnitude of 5th harmonic increases significantly, almost doubling.

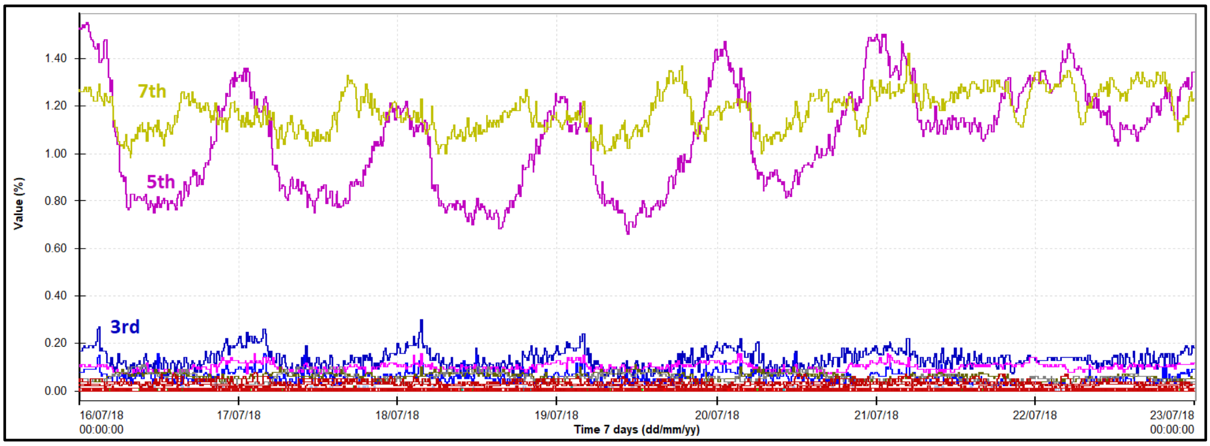


Figure 2-3 – Harmonic profiles for an example week (10 minute samples, displayed in Pronto).

A particularly interesting early piece of learning from the pilot trial is how the timing of the monitoring period affects the results. Typically, power quality monitoring and assessments are done for week-long periods; however, the pilot trial ran for many weeks, so there was enough data to investigate whether choosing different week-long windows would affect the overall results of analysing the harmonics.

To assess this effect, the 10-minute interval Vab harmonic data for the 3rd, 5th, and 7th harmonic orders was analysed using a “sliding window” approach. This approach calculated the summary statistics (95th percentile values) for all possible week-long “window” periods of data within six weeks of monitoring data, with the start date and time “slid” by 10 minutes for each window.

The results of the “sliding window” analysis are shown in Figure 2-4, which shows that the start time of a standard week-long monitoring period does have an effect on the 95th percentile values, which are typical summary statistics for PQ data. Figure 2-5 summarises the effect on the 95th percentile values, in terms of the maximum, minimum, and average (mean) values for all possible week-long windows within the six weeks of data. The most significant difference in the figure is for the 3rd harmonic order, where the maximum value is 21.1% higher relative to the minimum. For the 5th harmonic order, the relative difference is 7.9% and for the 7th harmonic order the difference is 12.2%.

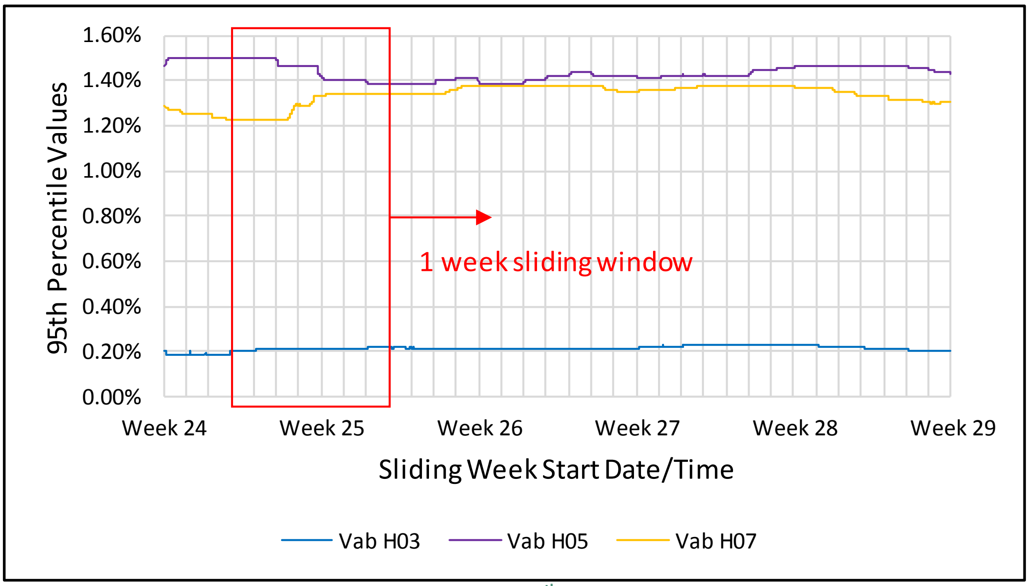


Figure 2-4 – Effect on voltage harmonic summary statistics (95th percentile values) by changing the start date and time of a standard week-long monitoring window (Vab, based on 10 minute interval data).

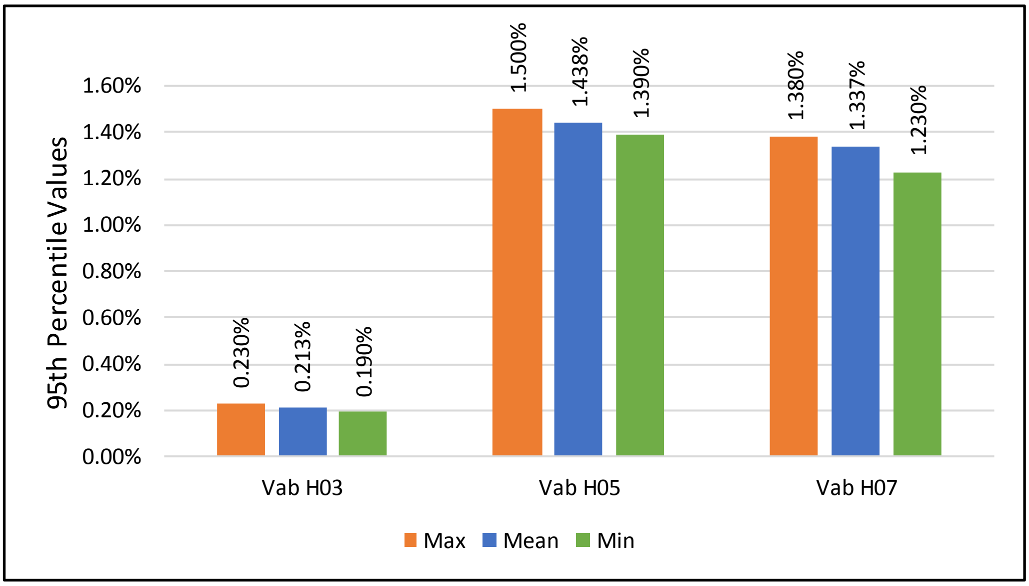


Figure 2-5 – Summary of effect on harmonic summary statistics by changing the start date and time of a standard week-long monitoring window (Vab, based on 10 minute interval data).

The pilot trial also provided valuable experience and learning for the project team around installation practicalities, expected data volumes, PQ monitor integration, and PQ analysis processes, which will all be useful for the upcoming project activities.

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, are being laboratory tested as part of PNPQA.

Progress within this reporting period

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

WPD asset data was analysed to identify types of VT (manufacturer and model) that are representative of those used by WPD at 11 kV and 33 kV. Examples of these representative VT types were sought from within the business; however, examples could not be found for all types due to limited availability of scrapped or spare units. Three example VTs were obtained, shown in Figure 2-6, and these have been delivered to the UoM.

Figure 2-6 – VTs from within WPD used for testing. From left to right: 3-phase 11 kV VT from a metering unit; 3-phase 11 kV VT from a withdrawable switchgear panel; 3-phase 33 kV pole-mount outdoor VT.

No example 33 kV switchgear-mounted VTs could be found from within WPD, therefore two new 1-phase units are being purchased from separate suppliers for testing. Testing 33 kV VTs is essential as they will be used for a significant amount of the PQ monitoring within PNPQA.

Although examples of representative types of 11 kV pole-mounted VTs could be found, none were obtained for testing as they are not usually used for PQ monitoring.

The UoM has designed the test circuit, sourced test equipment, and developed software to control the tests and perform data acquisition (DAQ). The test set up is shown in Figure 2-7 and comprises:

- Control and DAQ computer (not shown): This has several functions:
    - Signal generation: Test waveforms are generated consisting of a sine wave at the fundamental frequency (50 Hz) superimposed with one or more sine waves at different harmonic orders from the 2^{nd} (100 Hz) to the 50^{th} (2500 Hz). Separate waveforms are generated for each of the 3 phases and are output at a low voltage (<10 V peak) and low power as an input to the power amplifiers;
    - DAQ: Measurements are taken and recorded from the voltage dividers on the high voltage (HV) side of the VT under test, and from the secondary wiring on the low voltage (LV) side of the VT; and
    - Control: Sequencing of tests including automatically changing the superimposed harmonics being generated, and storage of results.

- Power amplifiers: These take the low voltage and low power test signals generated by the control and DAQ computer and amplify them to a higher voltage (<100 V) and higher power signal. These signals then go into the step-up transformers;
- Impedance matching resistors: These balance the output power of the amplifiers before the test signals go in to the step-up transformers;
- Step-up transformers: These increase the test signal voltage from <100 V to 11 kV or 33 kV phase-to-phase, as an input to the HV side of the VT under test;
- Voltage dividers: These provide measurements of the HV test signals at 11 kV or 33 kV in to the control and DAQ computer. The computer controls the HV signals so the voltage at the fundamental frequency is correct, and each of the superimposed harmonics is at 1% of that voltage; and
- VT under test: The example VT being tested receives the test signal via its HV primary terminals, which are connected to the HV side of the step-up transformers. The transformed signals are output via the LV secondary terminals (nominally 110 V phase-to-phase), which are measured by the control and DAQ computer.

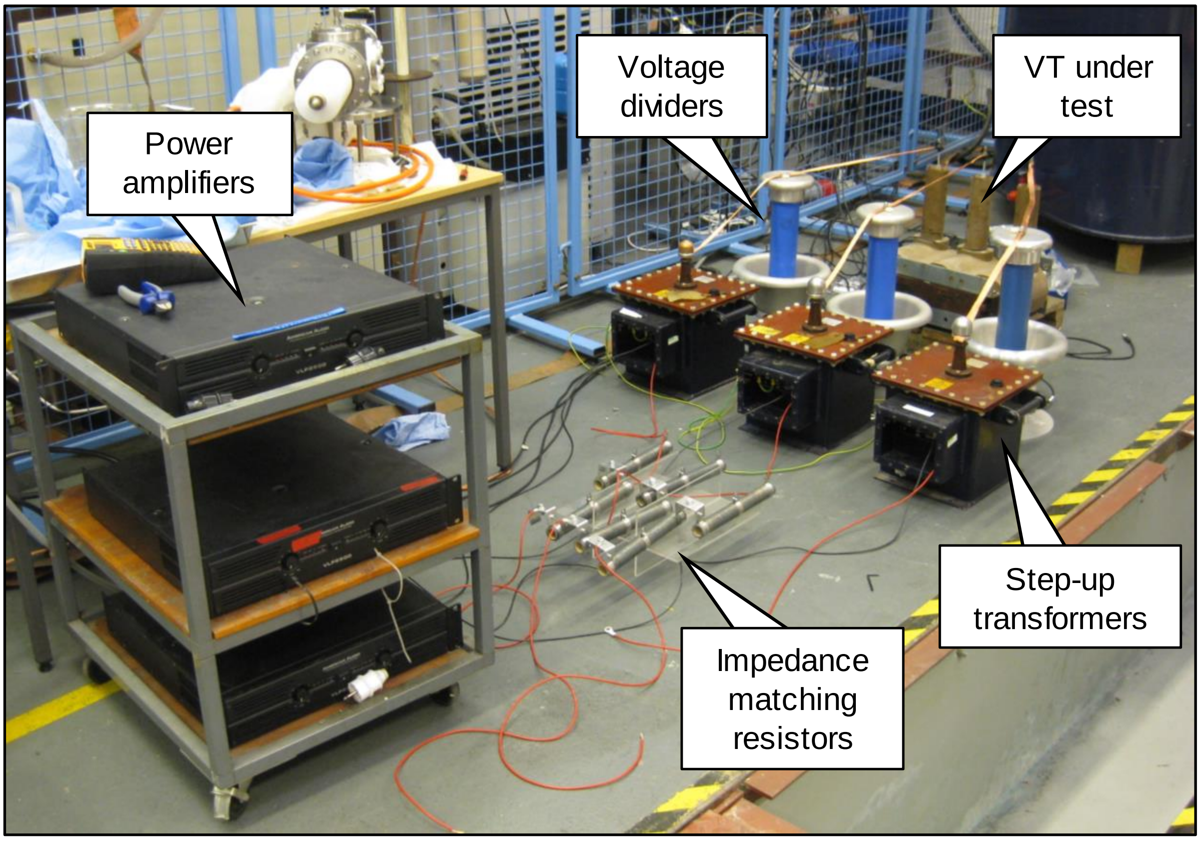


Figure 2-7 – VT testing circuit set up in The University of Manchester.

The UoM have so far tested the 3-phase 11 kV VT from a metering unit and the 3-phase 33 kV pole-mount outdoor VT. The harmonic frequency responses of each of these VTs are shown in Figure 2-8 and Figure 2-9 respectively. The figures show the output-to-input ratio, which for the 11 kV VT is nominally 10×10^{-3} (100:1, based on 11 kV primaries and 110 V secondaries on the VT), and for the 33 kV VT is nominally 3.33×10^{-3} (300:1, based on 33 kV primaries and 110 V secondaries on the VT).

The results from the two VTs currently tested are consistent:

- The output/input ratios at the nominal frequency (50 Hz) closely match what would be expected based on the transformer nameplate ratios;
- The output/input ratios decrease (attenuate) as frequency increases; in other words, the higher the frequency, the lower the signal is on the secondary side of the VT. At the 50th harmonic the output signal magnitude is approximately 50% less than what would be expected based on the transformer ratio alone;
- There are differences in the output/input ratios for each of the 3 phases. This is due to the construction of a 3-phase transformer, which results in asymmetry in the magnetic flux distribution between the phases, which results in voltage differences; and
- Additionally, the transformer construction and asymmetry leads to the variation in output/input ratios between the phases at the 3rd, 5th, and 7th harmonic, which is particularly apparent for the 11 kV metering unit VT (Figure 2-8).

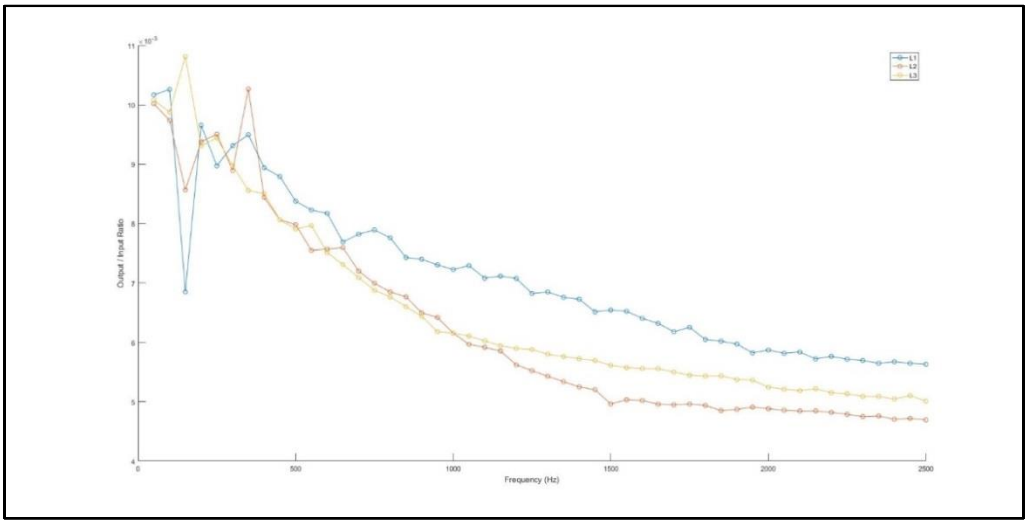


Figure 2-8 – Harmonic frequency response for the 3-phase 11 kV VT from a metering unit.

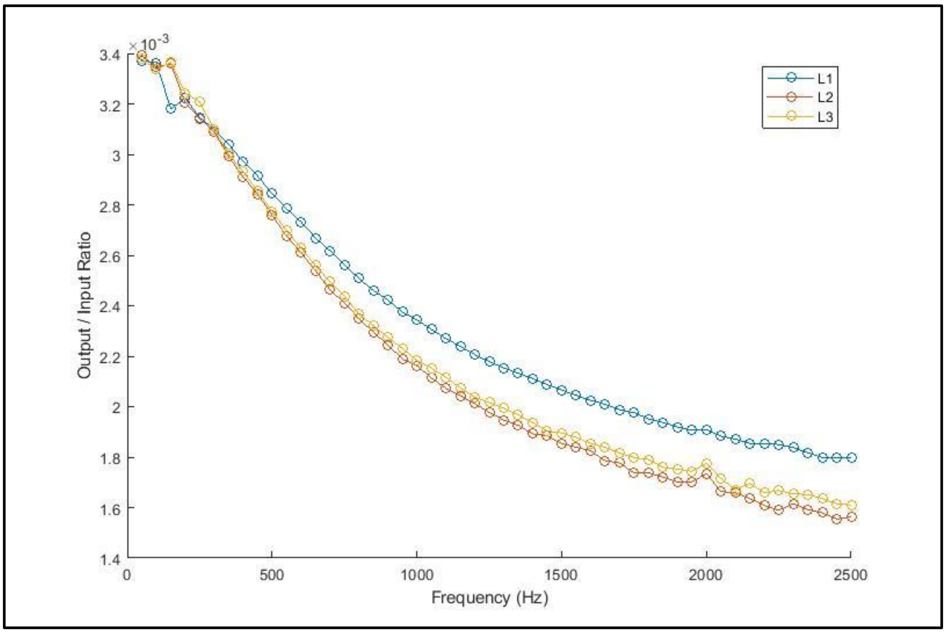


Figure 2-9 – Harmonic frequency response for the 3-phase 33 kV pole-mount outdoor VT.

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

2.3.3 Trial Area & Site Selection

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

Progress within this reporting period

The initial step was to develop selection criteria, which were based on the requirements set in the original NIA registration and formed the basis of the selection process:

1. **Selection criterion 1 – LCT penetration**: The NIA registration states that "two contrasting areas" of "Primary Network" shall be used for the trials, one "with a high penetration of LCTs" and the other "with a low penetration of LCTs". Two metrics were developed to assess different areas of Primary Network (33 kV networks in the West Midlands licence area for PNPQA) against these requirements, based on demand and generation:
    a. "High" LCT score: For this, areas score higher if they have significant connected capacities of LCT distributed generation (DG) at 33 kV and 11 kV in comparison to the firm capacity of the infeeding substation, and also if LCT DG outweighs non-LCT DG (e.g. diesel, gas turbines); and
    b. "Low" LCT score: Areas attract a higher "low" LCT score if they do not feature significant connected capacities of any DG at 11 kV and 33 kV in comparison to the infeeding substation firm capacity. Furthermore, if there is some DG within an area, the area will attract a higher score if it is non-LCT DG.
2. **Selection criterion 2 – additional features**: The "high" and "low" LCT scoring based on generation and demand are adjusted based on additional features such as the presence of rapid EV chargers, new LCTs about to connect, and the presence of existing PQ issues. The adjusted scores for each of the 33 kV network areas considered are shown in Figure 2-10.
3. **Selection criterion 3 – similar networks**: The NIA registration calls for the two network areas to allow for "comparisons to be made"; therefore, they should be similar except for the penetrations of LCTs. Similarity was assessed by:
    a. The network areas were compared against each other using several metrics: the total circuit length, the proportion of circuits that were overhead line, and the infeeding substation demand;
    b. Based on the similarity metrics, four groups of areas were found that shared similar values across all three metrics;
    c. Two of these groups were ignored as their characteristics limited the learning that they were likely to deliver: either the total circuit lengths were short

(<40 km) – with therefore little network to monitor – or the areas were too dissimilar to all the other areas – so any learning is less easily generalised; and

   d. The remaining two groups contained areas that contained predominantly overhead lines (>70%) and had total circuit lengths of either 40-80 km or 100-180 km. The top-rating "high" and "low" LCT areas from each group were selected as candidates for assessment in more detail according to the final selection criterion below.

4. **Selection criterion 4 – usable sites**: For a candidate area to be used as a trial area for PNPQA, it must be feasible to monitor PQ at the sites within the area. This was assessed in two stages, with the top-rated areas targeted first:
   a. Desktop analysis of asset and site information, to identify what equipment should be available on site (VTs and CTs) for PQ monitoring; and
   b. Site surveys, which included:
      i. Verification of equipment available on site;
      ii. Checking secondary terminals for VT and CT connections;
      iii. Checking possible installation space, access to power, and external access (e.g. for antenna connections);
      iv. Mobile communication signal strength checks; and
      v. Check substation layout and running arrangement.

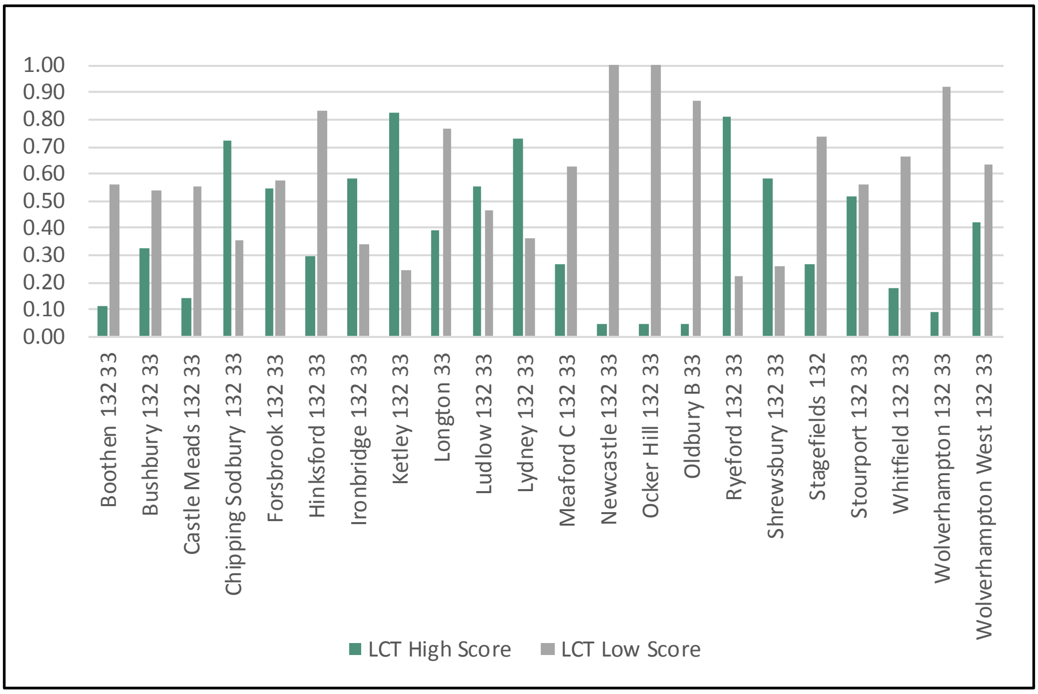


Figure 2-10 – LCT scoring for the 33 kV network areas (BSPs) in WPD's West Midlands licence area

Two strong candidate areas have emerged from the group of areas with total circuit lengths of 100-180 km:

- "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.

Site surveys have been completed at all the sites within the Meaford C network area, and the majority are suitable for PQ monitoring as part of PNPQA. Site surveys with the Ryeford network area are planned for October 2018.

2.3.4 PQ Monitor Integration

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

Progress within this reporting period

A market review of PQ monitors has been completed, which has revealed several potential manufacturers and also the range of features available on the market.

Two PQ monitors from different manufacturers have been obtained for bench testing. The tests are investigating the interfaces available on the monitors, to check the feasibility of using them to enable remote communications of PQ data. A third PQ monitor is on order and will be bench tested once it is delivered.

An overall architecture for the PQ monitoring and communication solution for the widescale trial has been outlined. A high-level summary of this architecture is shown in Figure 2-11.

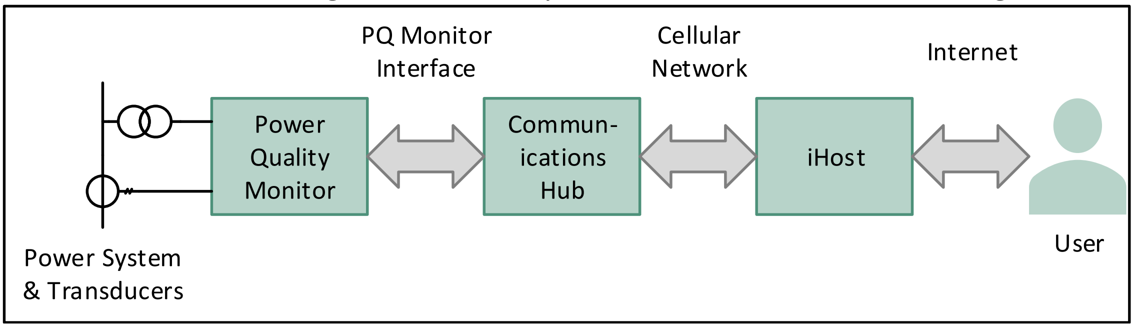


Figure 2-11 – Summary of overall architecture for PNPQA PQ monitoring and communication.

2.3.5 PQ Analysis Automation Software

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

Progress within this reporting period

Meetings have been held with PQ experts with WPD Primary System Design (PSD) to understand current processes and future expectations, in order to capture requirements for the automation software. The outputs from these meetings have formed the basis of a specification that is currently being drafted for the software.

2.3.6 Modelling & Studies

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

Progress within this reporting period

No activities were planned or took place during the current reporting period.

2.4 Next Steps

The activities described below are planned for the next reporting period and will mark the transition from phase 1 (Design) to phase 2 (Build).

The testing of VTs at the UoM will continue in to the first half of the next reporting period. A third 3-phase 11 kV VT sourced from within WPD will be tested, followed by two single phase 33 kV units that are currently being manufactured. The VTs to be tested are representative of those used within WPD and some are also in use in the trial areas, so information about their harmonic performance will be directly relevant to the PQ monitor trial. It is planned to disseminate the findings of the testing through a conference paper.

Preparations for the widescale trial of PQ monitors will increase over the next reporting period. This will begin with the selection of trial areas and sites being confirmed, following site surveys in the high LCT area (around Ryeford BSP). Bench testing of demo PQ monitors will be completed once a third demo PQ monitor is delivered, and the results of the testing will allow interface firmware to be developed and tested to enable remote communications from the monitors. PQ monitors will be purchased and the interfacing hardware will be produced. A specification for the PQ data retrieval and analysis software will be prepared and then reviewed by WPD, enabling software development to start. At the end of the next reporting period it will be possible to begin the first PQ monitor installations as part of the widescale trial.

Work on the modelling and studies aspect of PNPQA will also begin. The modelling software choice will be decided following a review of available modelling software for PQ studies. The study objectives and methods will be defined and reviewed within WPD. Finally, data will be collected and used to build power system models for PQ studies.

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	340.0	339.1	-0.9	-0.3%
WPD Project Management	45.7	3.0	2.6	-0.4	-14.2%
Technology and Installation	553.8	9.2	8.9	-0.3	-2.9%
Contingency (Unsanctioned)	123.6	0.0	0.0	0.0	-
TOTAL	**1358.5**	**352.2**	**350.7**	**-1.5**	**-0.4%**

4 Progress towards Success Criteria

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

1. Impact of LCTs on power quality and harmonics within primary networks better understood.
    - VT testing underway at The University of Manchester to validate the accuracy of equipment used for PQ measurements.
    - Preparations are being made for the widescale trial of communicating PQ monitors, which shall provide detailed data on the power quality within primary networks including the impact of LCTs.
2. Power quality monitors installed at trial locations and remote retrieval of data successfully demonstrated.
    - Trial area and site selection substantially complete.
    - Work begun on interfacing with different PQ monitors to enable remote communications as part of the trial.
    - Monitoring pilot has demonstrated remote retrieval of data from a single PQ monitor.
3. Tools for automating power quality data retrieval and analysis demonstrated.
    - Requirements have been captured from WPD PQ experts.
    - Specification for the automation software system has been started.
4. Policies created to implement project outputs in WPD's business.
    - This will follow later in the project (during phase 4 – Report).

5 Learning Outcomes

5.1 Phase 1: Design

The learning across different areas of Phase 1 during the current reporting period is summarised below:

- VTs for harmonic monitoring
    - 33 kV and 11 kV VTs pass through signals at the harmonic frequencies typically measured (up to the 50th) but introduce attenuation in the output magnitude at higher frequencies.
    - The construction of 3-phase VTs leads to the output voltages having differences between phases and at the 3rd, 5th, and 7th harmonic orders.
- PQ within Primary Networks
    - The timing of a typical week-long PQ monitoring period has an effect on the monitoring results, with significant variations in the 95th percentile harmonic values between different week-long periods. This has been observed for a single site based on just 6 weeks of data, so the effect may be more pronounced at other sites and using data from a longer period (e.g. a year).
- PQ monitors
    - Market research has revealed at least 20 manufacturers of PQ monitors that meet the basic requirements expected for PNPQA. However, none have identical interfaces meaning bespoke work is needed for each to enable remote communications with the monitors.

6 Intellectual Property Rights

No new foreground IP has been generated by PNPQA at present.

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 WPDs 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 , we give details of our top five current risks 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: Top five current risks (by rating)

Details of the Risk	Risk Rating	Mitigation Action Plan	Progress
Nortech resources are unavailable	Moderate	1. Nortech to assign dedicated resources 2. Stand-in resources to be identified to cover staff absences	Dedicated Nortech project manager assigned. Supporting team mobilised for project.
Nortech does not deliver required performance	Moderate	Appointment of Nortech based on technical skills and previous good delivery	No changes since project start.
Monitoring equipment system integration not possible	Moderate	1. Include requirements for interface in procurement specification 2. Engage with suppliers to get their support	Bench testing underway with PQ monitors to check interfaces for integration
No or few sites available for trials	Moderate	1. Develop selection criteria based on what is available 2. Consider other licence areas if few sites in West Midlands	Trial site surveys (50% complete) indicate numerous sites are available.
Trial sites have poor communications	Moderate	1. Consider comms reception as part of trial site selection 2. Have alternative sites selected with better comms 3. Obtain other comms (e.g. broadband) if other options exhausted	Trial site surveys (50% complete) indicate communications are available at most sites.

provides a snapshot of the risk register, detailed graphically, to provide an on-going understanding of the project's risks.

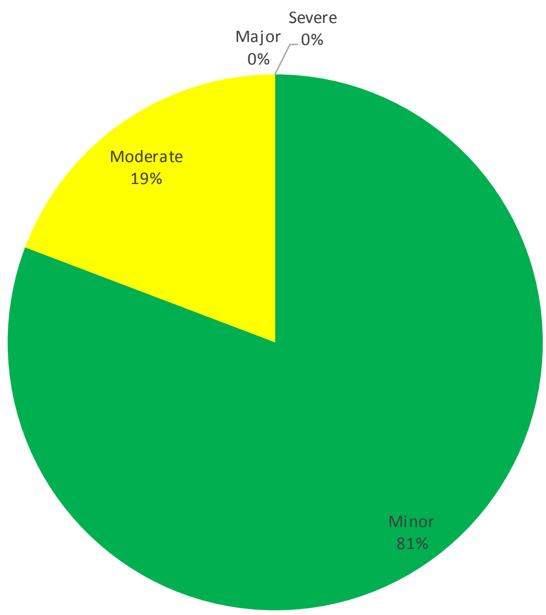
Table 7-2: Graphical view of Risk Register

Likelihood = Probability x Proximity		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
	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)	1	0	0	0	0
	Less likely to occur/Mid to long term (6-10)	0	0	2	0	0
	Very unlikely to occur/Far in the future (1-5)	1	4	15	3	0
		Impact				

	Minor	Moderate	Major	Severe	
Legend	**21**	**5**	**0**	**0**	**No of instances**
Total	**26**				No of live risks

Error! Reference source not found. provides an overview of the risks by category, minor, oderate, major and severe. This information is used to understand the complete risk level of the project.

Table 7-3: Percentage of risks by category



8 Consistency with Project Registration Document

The scale, cost and timeframe of the project has remained consistent with the registration document, a copy of which can be found here:

https://www.westernpower.co.uk/downloads/2039

9 Accuracy Assurance Statement

This report has been prepared by the PNPQA Project Manager (Jonathan Berry), reviewed and approved by the Future Networks Manager (Roger Hey).

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
DG	Distributed Generation
EV	Electric Vehicle
HV	High Voltage
IPR	Intellectual Property Rights
LCT	Low Carbon Technologies
LV	Low Voltage
NIA	Network Innovation Allowance
PNPQA	Primary Networks Power Quality Analysis
PSD	Primary System Design
VT	Voltage Transformer
UoM	University of Manchester
WPD	Western Power Distribution