QUEST
An overarching control system

QUEST Trials, Design and Specification Summary Report

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Project Partners

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Name	Role	Date
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APPROVAL

Name	Role	Signature & date
Victoria Turnham	Head of Network Innovation	Victoria Turnham Digitally signed by Victoria Turnham Date: 2022.06.30 15:08:35 +01'00'
Maurice Lynch	QUEST Programme Manager	Maurice Lynch Digitally signed by Maurice Lynch Date: 2022.06.30 15:01:11 +01'00'

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EXECUTIVE SUMMARY

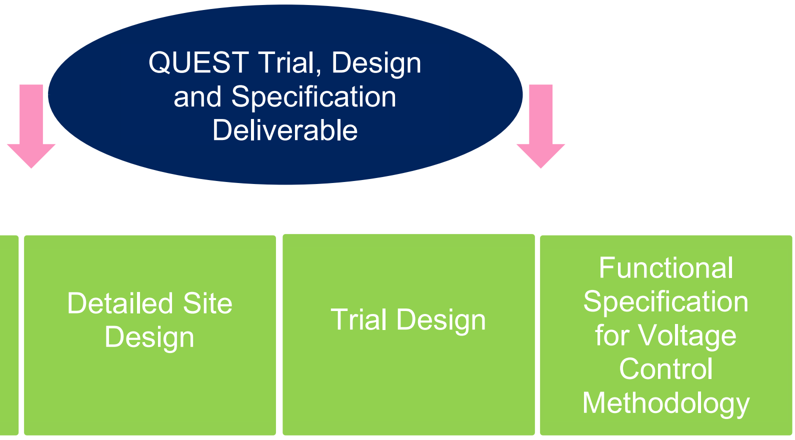
This report, "QUEST Trials, Design and Specification", is the third of nine key project deliverables for the QUEST NIC (Network Innovation Competition) project.

For the purposes of this report, "the project" refers to the NIC-funded project, "QUEST" refers to the overarching system, and the "optimisation software" refers to the software used to enable QUEST.

This report follows the second project deliverable, QUEST System Design and Architecture Lessons Learned, published in December 2022, which provided an in-depth review of the architecture options based on the use cases in the first deliverable, QUEST Initial Report – Use Cases, in addition to a specification for the network models and modelling regime that aligned with the architecture options.

This report will detail the chosen QUEST functional specifications for the architecture, voltage control methodology, trial design and detailed site design, based on the research and learning from the previous deliverables. This will allow for development of the QUEST system control and for onsite works to commence, which will feed into the next project deliverable.

Figure 1: Deliverable workstream breakdown



This project deliverable comprises four workstreams: the functional specification for architecture and trial design workstreams were led by Schneider Electric (SE); the functional specification for voltage control methodology workstream was led by Smarter Grid Solutions (SGS); and the detailed site design workstream was led by Fundamentals Ltd. All partners were tasked with producing a detailed report for each workstream as part of this deliverable. Section 2 of this report provides an overview of all work stream reports, and the full reports are also published and available on ENWL's QUEST website.

The functional specification for chosen architecture report outlines the full functional specification of the QUEST overarching control system and details the co-ordination between each of the individual systems in addition to instructions received by National Grid Electricity System Operator (NG ESO), and the action each system takes when these instructions are received. The report also provides a high-level overview of the main architecture diagram and proposed potential mock-up of the user interface.

The functional specification of voltage control methodology report describes the voltage control methodology defined by Schneider Electric as per the architecture specification by:

- Defining the QUEST philosophy, which provides the functional specification for how QUEST will deliver its voltage methods to achieve its objective for overarching control.
- Using the modelling regime (constructed in a previous SGS QUEST research work packages) to emulate a QUEST solution upon a simulation of ENWL's electrical network in the QUEST trial area.
- Creating a scenario analysis that tests QUEST's functional specification for the voltage methodology and executing these scenarios to show how QUEST provides over-arching

control and how these impacts are experienced by the network via key performance indicators.

The trial design report details the testing strategy that will be applied during the QUEST trials, including a high-level description of the use cases that will be used to assess QUEST functionality. The purpose of these use cases is to provide a way to confirm that the implemented QUEST functionality captures the requirements defined during the QUEST design phase, and that QUEST satisfies all other objectives defined so far.

The detailed site design report specifies the requirements for onsite works to be carried out by Fundamentals within the QUEST trial area, which has been identified as Whitegate GSP. This report details the findings from the site surveys conducted and outlines the work and hardware installation that will be carried out at each of the Bulk Supply Points (BSPs) and primary substations to allow the trials to be carried out.

These workstream reports were delivered via workshops held virtually from January 2022 to June 2022. The main challenge for this deliverable was carrying out this work virtually, whilst also ensuring all workstream reports were aligned, with no contradictions or misalignments. To ensure the workstreams were aligned and covered the project objectives, ENWL's technical innovation engineers took on the role of ensuring all reports produced by the project partners were aligned and referenced one another.

The learning output from this deliverable provides the functional specification for the QUEST architecture and voltage control methodology, in addition to the trial design and detailed site design. This deliverable will support the QUEST software and power system model development, along with the configuration of site installation lessons learned, which are required for the next deliverable, due in June 2023.

1 INTRODUCTION

1.1 Purpose of this report

The purpose of this report is to provide a summary of four workstream reports that form the third QUEST project deliverable: the QUEST Trials, Design and Specification Report. This deliverable comprises four main streams of work:

- Specification of chosen architecture
- Specification of chosen voltage control methodology
- Trial design
- Detailed site design

These were carried out in parallel to fulfil the programme requirements for this deliverable. This report outlines how these were carried out and what learning outcomes were achieved within each. The report also provides insight into the challenges encountered and how these were overcome to ensure requirements were completed on time and to the required standard. Finally, the report provides an overview of the main conclusions and learning outputs within each workstream, and details how this will feed into next project deliverable, QUEST Interim Report – System Design and Technology Build Lessons Learned, due to commence in July 2022 and complete in June 2023.

1.2 Project update

The project is currently on track to meet its aims, objectives, and all deliverables (outlined within the full submission), as per the project plan. One of the main challenges within the early stages of the project was outlining the project's use cases. The use cases are critical as they set out the architecture and voltage control requirements and align to the project's overall objectives and goals. Over the course of the project the uses cases have evolved, based on the project learning from deliverables one and two. This third deliverable outlines the functional specification that will be taken forward into the software and architecture development phase, during which the project team will begin to build the architecture software control algorithm. Therefore, from this stage onwards there will little to no change to the use cases.

It was noted in the QUEST System Design and Architecture Lessons Learned report that due to COVID restrictions many meetings were held virtually and not in-person, which was challenging. Due to the relaxing of COVID restrictions by the UK government, the QUEST project team has been able to return to face-to-face meetings and in-person workshops, which has supported further collaborative development and enabled more interactive project meetings.

Finally, as outlined in the QUEST System Design and Architecture Lessons Learned deliverable report, the site surveys were completed in January 2022 for the AVC installation at nine BSPs and primaries. This has enabled the drafting of design reports for this work by the Fundamentals team, which are currently being reviewed by ENWL's design authority. Once approved, outages will be scheduled to allow Fundamentals to carry out the work outlined within the design reports. It is estimated that all associated work on the AVC installations will be completed by March 2023. At present, OLTCs (On-Load Tap Changers) are being installed on the Travis CT feeder out of Royton primary, which is within the Whitegate GSP trial area. To date, three out of seven of the OLTCs have been installed on this feeder, with the remaining four to be installed by the end of July 2022.

1.3 QUEST Trials, Design and Specification development process

In order to achieve the required outputs of this deliverable, which will feed into the next stage of the project, a development process was created. This was to allow for the individual workstreams to achieve their respective goals within this deliverable, but also to ensure that they remain in line with the project objectives and governance.

As stated in the Executive Summary of this report, there are four individual workstreams within this deliverable:

1. Functional Specification for chosen Architecture
2. Functional Specification for Voltage Control Methodology
3. Trial Design
5. Detailed Site Design

Figure 1.3.1: QUEST deliverable three workstream structure

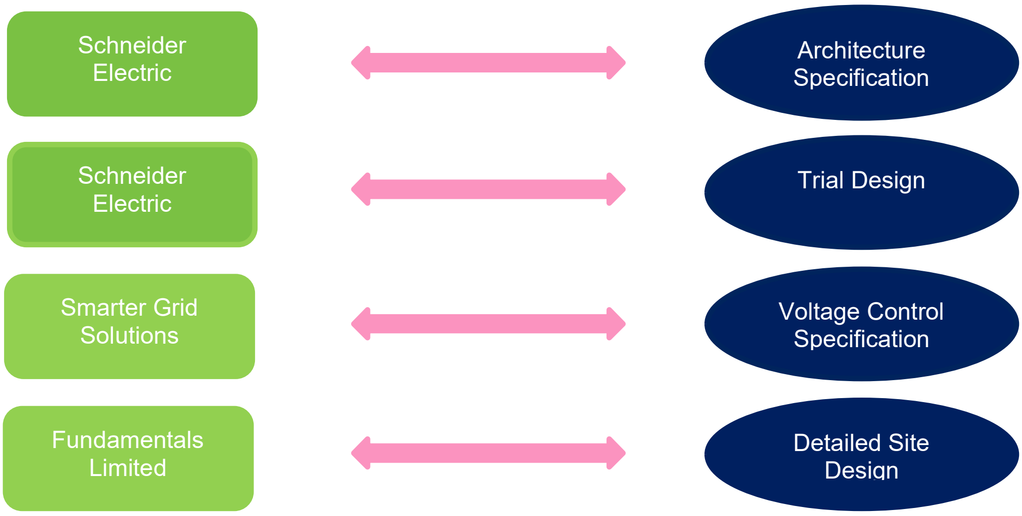


Figure 1.3.1 shows the structure of each individual workstream and which partner was responsible for report delivery.

SE led on the architecture specification and trial design reports as they are responsible for software development, hence they were best placed to lead on these two individuals workstreams. All other partners were heavily involved in the input and review of these reports, with the ENWL team providing strategic direction and requisite governance to ensure the output of the research and drafted reports meets the objectives of the project.

SGS led on the voltage control specification report due to their expertise in power system modelling. It was critical that these workstreams were closely aligned, as the modelling informed the capabilities of the architecture specification report.

The detailed site design report was led by Fundamentals, as they were conducting the onsite AVC installations and had already completed the site surveys for each of the nine individual BSPs and primary substations, feeding into the design reports currently being drafted. Fundamentals had previously completed site works within the CLASS project and were therefore well-placed to complete this work for QUEST, due to their experience.

There were two meetings per week for the architecture specification workstream, and one meeting every two weeks for all other workstreams, which ran until the end of June 2022. The reason for the focus on the architecture meetings compared with the other workstreams is that architecture meetings informed the direction scoping of the other workstreams. Hence it was key that the architecture was defined as early as possible so that the requirements of the other workstreams could be understood and aligned to the architecture.

2 DELIVERABLE WORKSTREAM REPORTS

2.1 This section of the report provides an insight into each of the workstream report outputs. The aim is to provide a high-level overview with all the key learning points distilled. For readers requiring further information and technical detail the workstream reports are available in support of this summary publication. Functional specification for chosen architecture overview

The QUEST objectives outlined in the QUEST Initial Report - Use Cases document were reviewed prior to commencing system architecture work to ensure that all aspects of the overarching control were aligned, and the core objectives of the project fulfilled. As part of this review, a second set of objectives, the QUEST core operational objectives for both normal and emergency system conditions, were identified. These are outlined below:

Normal conditions

- Co-ordinate operation of system voltage control techniques by adjusting them in a way to gain as many benefits as possible from each voltage control technique, while preventing counteraction between them.
- Enhance operational efficiency by minimising the 33kV system losses.
- Maintain statutory voltage limits as per ESQCR.

Emergency conditions

- Put the existing voltage control techniques in appropriate mitigation modes in order not to block provision of the emergency response to the ESO.

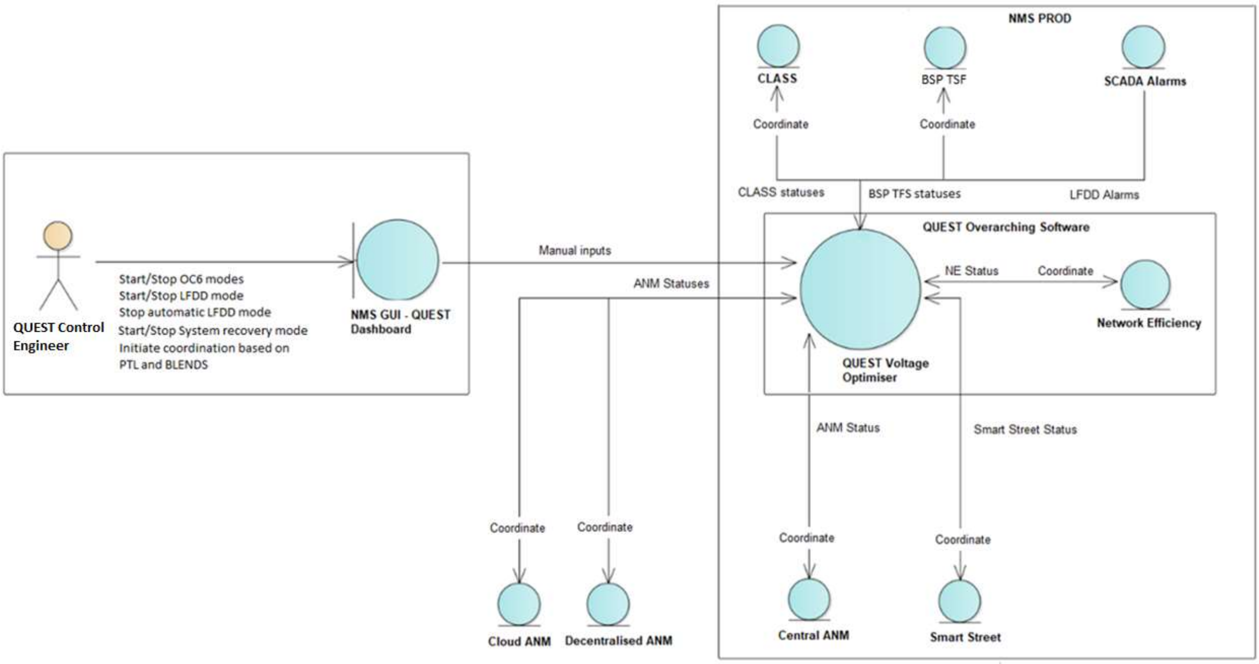
In order to satisfy its objectives, QUEST operates in real time. QUEST is aware of the statuses of all the voltage control techniques and based on all inputs provided, it performs appropriate co-ordination actions. QUEST co-ordination actions refer to putting the voltage control techniques into a state that either prevents or resolves conflicts that happen between them. By doing so, QUEST reacts either proactively or responsively. If QUEST reacts proactively, the states into which voltage control techniques are put are referred to as “safe modes”. A “safe mode” is a state which proactively places a voltage control technique at a level which results in that part of the system staying within statutory voltage limits whilst still being physically achievable by the relevant network voltage control asset. If QUEST reacts responsively, the states in which voltage control techniques are put are referred to as “mitigation modes”. A “mitigation mode” is one which places a voltage control technique or active network management (ANM) system responsively into a state appropriate for an emergency or unplanned condition.

In the case of proactive co-ordination, QUEST considers the priorities of voltage control techniques that are pre-defined by the QUEST control engineer (CE). Based on the pre-defined priorities and desired function levels of each voltage control technique, QUEST performs appropriate co-ordination actions. Another of QUEST’s core objectives is to enhance the operational efficiency, under normal system conditions, by minimizing the 33kV system losses. For that purpose, an additional voltage control technique, Network Efficiency Mode, is introduced through the QUEST overarching software. In addition to satisfying its defined objectives, QUEST also enhances the CLASS functionality. As an overarching software that has awareness of all other voltage control techniques operating in the network, QUEST can better adjust the CLASS primary substations in order to satisfy CLASS committed targets, but by trying to minimise its effect on other voltage control techniques. In order to facilitate this enhancement, QUEST introduces additional levels of voltage reduction for the CLASS primaries, as well as the Tap Stagger Functionality on a BSP level (BSP TSF).

2.2 Functional specification for chosen architecture report output

The main architecture diagram, displaying QUEST as an overarching software, is shown in **Error! Reference source not found.**.

Figure 2.2.1: QUEST – main architecture diagram



On the right side of **Error! Reference source not found.**, ENWL's NMS production system is shown with the QUEST overarching software in the centre. QUEST is built on the single ADMS Network Model containing all relevant network static data including that from the LV network. The network model is built from multiple data sources via the data interface built as part of the main NMS project and it is capable of fully modelling the distribution network, including single customers, all conducting equipment, Distributed Energy Resources (DERs), different types of load, and all the devices and their local automation.

Dynamic data provided to QUEST includes real-time data obtained from SCADA, such as the status of remotely controlled devices (including BSP substation, primary substation and distribution substation transformer tap positions), monitored voltage values across the whole DNO network. It also takes in SCADA alarms, as well as the manually controlled device states, tags, and temporary elements including jumper cuts, earths, temporary generators, temporary switches and temporary substations.

By combining the static data with the dynamic data, the "as-operated" state of the network is determined, and it is provided to QUEST so it can perform its co-ordination based on the "as-operated" network topology.

Since it is located within the NMS system, QUEST is aware of the status of all the other existing systems in the NMS system (CLASS, SMST and Central ANM).

By using ICCP (Inter-Control Centre Communications Protocol) communication links, QUEST is also integrated with the external ANM systems, Decentralised ANM and Cloud ANM, and is aware of their statuses.

Having visibility of all the existing systems in the QUEST trial area, as well as the voltages across the whole DNO network, QUEST Overarching Software is able to provide full distribution network co-ordination. By performing full co-ordination, voltage profiles are managed with an appropriate balance between centralised and decentralised control hierarchy (QUEST Voltage Optimiser circle in the main architecture diagram is in charge for co-ordination of all voltage control techniques).

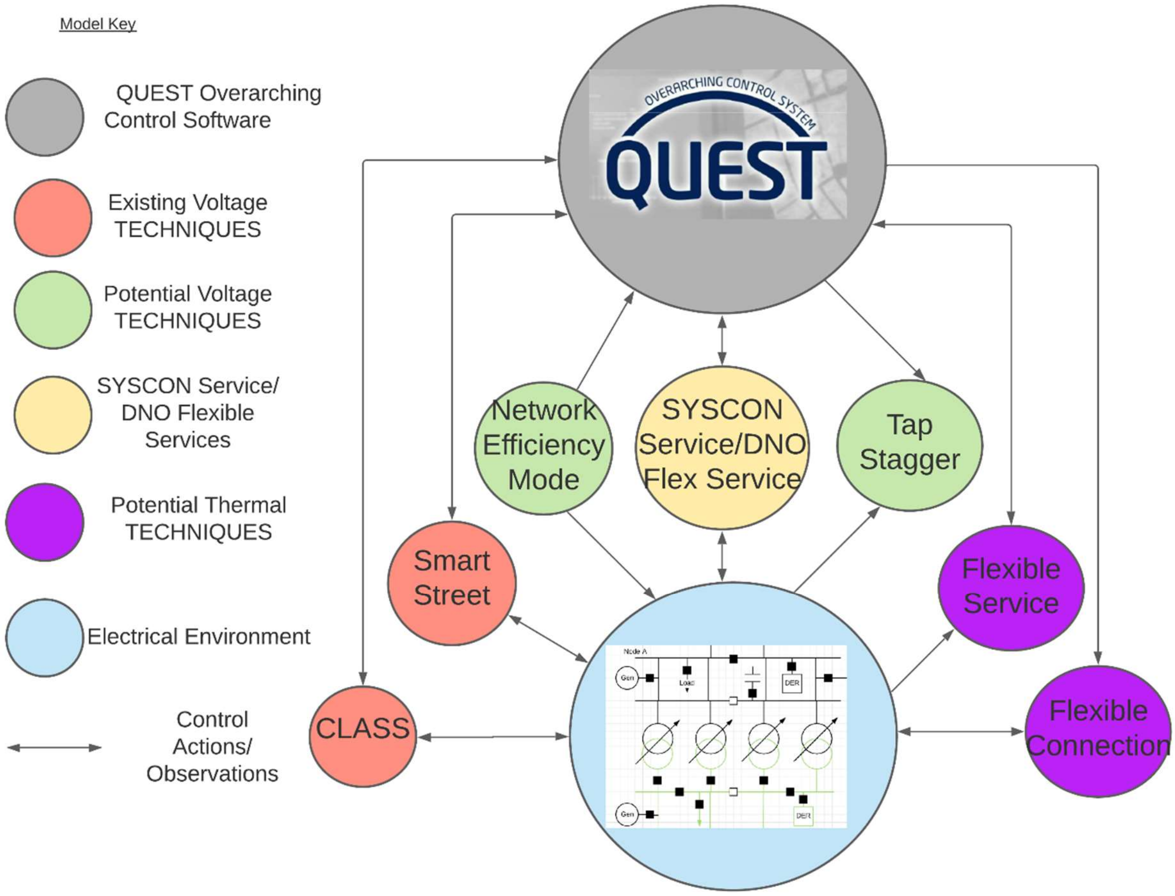
In addition to co-ordinating the operation of the existing voltage control techniques in the network, QUEST Overarching Software tries to increase the 33kV network efficiency whenever possible, by increasing the voltages on the 33kV distribution network. Network Efficiency (NE) is displayed in the main architecture diagram as an additional voltage control technique which is provided through QUEST Overarching Software and is also co-ordinated by the QUEST Voltage Optimiser. Based on the inputs provided to QUEST, QUEST determines and automatically performs appropriate co-ordination actions.

Additional details of the proposed architecture models, user interfaces and control methodologies mentioned in this section are provided in the main QUEST Functional Architecture Specification document, published on ENWL's QUEST website.

2.3 Functional specification for voltage control methodology overview

The high-level structure of the modelling regime is presented in **Error! Reference source not found.**.

Figure 2.3.1: QUEST – high-level structure of the modelling regime



The modelling regime enables simulation representative of the ENWL electrical distribution system (blue) via network modelling for both time-step and time-series analysis, observing key performance indicators as outlined below:

- **Total system demand:** Since this is a parameter that CLASS and Smart Street seek to reduce, or increase, it must be observed.
- **33kV system losses:** Since this is a parameter that Network Efficiency Mode will look to reduce, it must be observed.

- **External network generation:** Since this is a parameter that will alter due to demand changes, it must be observed.
- **Internal network generation:** Since this is a parameter that will alter due to demand changes, it must be observed.
- **Total system carbon intensity:** By converting external generation to the network, MWh generation (ESO) and internal network MWh generation (DNO), to CO2 per kWh, ENWL's carbon intensity can be determined. Showing how impacts to demand and generation can affect external and internal carbon intensity.

The following network control and optimisation techniques are applied to each part of the modelling regime, these are:

- Existing voltage TECHNIQUES (Red): CLASS, Smart Street
- Potential voltage TECHNIQUES (Green): Network Efficiency Mode, Tap Stagger BSP
- SYSCON Service/DNO Flexible Services (Yellow): Mandatory SYSCON Services such as LFDD and DSO Flexibility Services.
- Thermal TECHNIQUES: Flexible Connections (Purple).

The above described thermal and voltage techniques and within the modelling regime are then applied to relevant network assets within the electrical model, and their effects on electrical network parameters are observed. For example, bus-bar voltages and thermal branch flows are identified as key performance indicators.

- Identification of issues within the modelled electrical network, caused by conflicts between voltage TECHNIQUES achieving their objective BLEND FUNCTION LEVEL, to determine how QUEST's voltage control methodology can resolve these issues. **Note:** A BLEND FUNCTION LEVEL is the ratio of Techniques to achieve network set objectives.
- Analysis of QUEST's overarching voltage control methodology and impacts upon the simulated electrical network; in order to optimise and validate its methodology to shape the technical priority list development and how the methodology impacts the key performance indicators associated with the network operation.

The modelling regime is used to facilitate scenario analysis upon specific QUEST states which are analysed and identified as the most pertinent scenarios, at the present stage of the project.

A set of scenarios is defined in order to test QUEST's TECHNIQUES, regarding the individual TECHNIQUES applied, their impacts to the network and how QUEST provides over-arching control to co-ordinate conflict between objectives and physical network limitations – all of which affect the key performance indicators of the network. The result of the scenario analysis is validation of the functional specification for QUEST's voltage methodology.

2.4 Functional specification for voltage control methodology report output

The main output from this Scenario Analysis has achieved the following objectives:

- validated the functional specification of the voltage control methodologies defined by the QUEST control system architectures and use cases, and
- provided the impact of key performance indicators associated with the network operation.

It has achieved this by implementing multiple scenarios using the modelling regime to thoroughly test the functional specification related to each voltage methodology in isolation and in conjunction with one another, with any conflicts between methods regarding either voltage methodology objective conflict or physical network limit compliance conflicts, being resolved by QUEST's overarching control. As well as showing the benefits and limitations to key performance indicators each combination of voltage methods will affect.

Furthermore, the outputs of the scenario analysis show that QUEST's overarching control solution is fit for purpose., The functional specification for voltage control once applied as part of a real-time platform architecture, being delivered by Schneider Electric, will achieve the wider QUEST objectives upon ENWL's network.

Although, overall, the outputs from the scenario analysis have achieved the objectives above, it has also provided confirmations and insights into previous projected benefits and limitations identified in the projects original use cases report. These outputs can now be fed into the development of the QUEST architecture and QUEST trials to improve the delivery of the solution, both now and in the future.

Voltage TECHNIQUE outputs

CLASS: Delivering the CLASS demand reduction target will be affected by availability of assets and the voltage-demand relationship that exists in the model. Scenario 1 highlighted that to deliver the CLASS target, when it is achievable, it might not need all assets. However, when the voltage-demand relationship is weaker at certain parts of the day, more assets need to be included to achieve the target .This means ENWL can understand the variance in CLASS service delivery from its asset base and the ability to optimise this.

Network Efficiency Mode (NEM): NEM can provide benefit to the network by reducing system losses in the 33kV; however, the magnitude of these benefits can be small regarding the absolute losses reduction associated with reduction in current but aggregated over the period that NEM is active improves the benefits. NEM is also suited to support the likes of CLASS and Smart Street demand reduction targets.

Smart Street: Smart Street provides a demand reduction benefit, but that benefit could be increased further by broadening the voltage targets associated with its function levels used in the scenario studies reported here. In the scenario analysis, the settings were kept in line with CLASS voltage targets; however, due to the p.u. statutory limits being lower at LV (400V), changes to the configuration of function level would allow greater benefits to be unlocked. It has been noted that while the Smart Street function level used to reflect the function levels in the QUEST design, the reality is that at present Smart Street transformers only have three tap steps to reduce voltage below the nominal tap setting., Each tap step being 2.5% of nominal voltage – as presented in the final function design specification. This would equate to Smart Street function levels of 100% with a 0.925 p.u. voltage target; 66% with a 0.95 p.u. voltage target and 33% with a 0.975 p.u. voltage target. While this does not impact the conclusions of the scenario studies carried out, this issue should be resolved to ensure maximum operational benefits are achieved for Smart Street, and any revised studies carried out during the QUEST trial phase to reflect the final agreed Smart Street function levels. This applies to the scenarios reported here that involve Smart Street. This will be investigated as part of the QUEST trials.

Tap stagger: Tap stagger can provide a MVAr absorption service to the DNO and SO, instead of the construction and installation of alternate voltage control systems such as a STATCOM. However, since this behaviour is commenced by taking advantage of increased system losses there is an impact to carbon intensity when operating, therefore, a balance in benefits must be struck. Furthermore, tap stagger operations cause slight voltage rise on the secondary bus bar of the BSP, which needs to be monitored by QUEST to ensure this does not interfere with delivering other TECHNIQUE function levels.

QUEST conclusions

Conflict satisfaction and coordination applied by QUEST allowed for all TECHNIQUEs to be applied in concert with one another, some important observations were:

In certain cases, uncoordinated responses would result in "known voltage excursions", for example, setting Smart Street to its function level voltage target before CLASS has achieved its own, could cause a double impact to voltage reduction at LV. The QUEST team have identified this as a potential conflict and will optimise and prioritise each voltage technique based on performance indicator we are working towards in real time.

This behaviour will be investigated, as part of the QUEST trials, to determine the worst-case impacts to uncoordinated actions across a year. This will allow us to investigate optimizing of proactive setting of Smart Street, where the activation of CLASS may potentially occur and cause an LV excursion. This option is only required if a fast tap solution does not exist, where this solution exists, for example it would allow QUEST to place Smart Street into a safe mode instantaneously following CLASS activation. Then QUEST would calculate the function level due to the constraints applied under the CLASS activation.

Flexible connections: CLASS demand boost was shown to provide greater demand in the network to be satisfied by the higher voltage network as a service; however, previously curtailed generation was quick to utilise this released demand, cancelling out any CLASS boost service. QUEST must mitigate in this circumstance by holding DERMS/ANM setpoints to their pre-CLASS boost calculated positions, in order to ensure this service can be delivered.

CLASS: CLASS objective delivery suffered in some cases from not being able to achieve voltage targets associated with its function level due to discrete tap limits. Since QUEST offers much more observability of voltages across the network, it is possible that voltage targets associated with CLASS function level can also be optimised, since these targets are conservative in nature to consider unobserved voltage drop across the network. This update would facilitate the delivery of CLASS targets and aid the delivery of function level as part of being associated within a technique priority list.

Overall, QUEST offers benefit in not only delivering each individual TECHNIQUE but also in concert with one another, providing the actions to achieve over-arching control. The impact to this control is shown not only in the delivery of the objectives associated with each voltage TECHNIQUE but also the key performance indicators associated with the network.

For the most part each TECHNIQUE will improve these key performance indicators, such as demand reduction and system loss reduction reducing carbon emissions. However, certain TECHNIQUE objective fulfilment can reduce the overall impact of benefits and in some cases reverse them. Therefore, these benefits must be weighed against the limitations on a case-by-case bases. The importance being that visibility to make these decisions is required and provided by QUEST.

Additional details of individual system scenario analysis and the test benching regime are provided in the main QUEST Functional Voltage Control Methodology Specification document, published on ENWL's QUEST website.

2.5 Trial design overview

QUEST is specifically designed to integrate the discrete voltage management techniques into one overarching, co-ordinated and optimised system. By viewing and controlling the whole network, QUEST co-ordinates the often-competing objectives of these existing systems to ensure optimised operation whilst maximising benefits for the customers.

The voltage management techniques co-ordinated by QUEST are:

- EcoStruxure ADMS Real Time Active Network Management (Central ANM)
- External Real Time Active Network Management (Decentralized ANM)
- External Look Ahead Active Network Management (Cloud ANM)
- EcoStruxure ADMS Smart Street (SMST)
- QUEST Network Efficiency (NEM)
- EcoStruxure ADMS CLASS services

QUEST co-ordination is performed for the entire trial area (Whitegate) during the normal and emergency conditions. The available QUEST System Conditions (SYSCONs), dependant on national electricity system conditions, are:

- SYSCON-1 = System Recovery (Black Start)
- SYSCON-2 = Low Frequency Demand Disconnection (LFDD), Automatic activation
- SYSCON-3 = Low Frequency Demand Disconnection (LFDD), Manual activation
- SYSCON-4 = OC6 Demand Disconnection (OC6 DD)
- SYSCON-5 = OC6 Voltage Reduction (OC6 VR)
- SYSCON-6 = Normal System Operating State

QUEST has diverse ways of co-ordination during normal (SYSCON 6) and emergency (SYSCON 2,3,4,5) system states. During Black Start system state (SYSCON 1) QUEST does not perform co-ordination.

QUEST core operational objectives have been determined for both normal and emergency system conditions:

- Normal conditions
  - Co-ordinate operation of system voltage control techniques by adjusting them in a way to gain as many benefits as possible from each voltage control technique, while preventing conflict between them.
  - Enhance operational efficiency by minimizing the 33kV system losses.
  - Maintain statutory voltage limits as per ESQCR.
- Emergency conditions
  - Put the existing voltage control techniques in appropriate mitigation modes in order not to block provision of the emergency response to the ESO.

To satisfy its objectives, QUEST operates in real time.

QUEST is aware of the statuses of all voltage control techniques and, based on all inputs provided, it performs appropriate co-ordination actions. QUEST co-ordination actions refer to the process of putting the voltage control techniques in a state that either prevents conflicts or resolves conflicts that happen between them. By doing so, QUEST reacts either proactively or responsively. If QUEST reacts proactively, the states in which voltage control techniques are put are treated as “safe modes”. A “safe mode” is a state which proactively places a voltage control technique at a level which results in that part of the system staying within statutory voltage limits whilst being physically achievable by the relevant network voltage control asset. If QUEST reacts responsively, the states in which voltage control techniques are put are treated as “mitigation modes”. A “mitigation mode” is one which places a voltage control technique or active network management (ANM) system responsively into a state appropriate for an emergency or unplanned condition.

In the case of proactive coordination, QUEST considers the priorities of voltage control techniques that are predefined by the QUEST control engineer (CE) in the QUEST PROFILE. Based on the predefined priorities and desired function levels of each voltage control technique, QUEST performs the appropriate co-ordination actions. QUEST performs co-ordination actions among voltage control techniques based on the previously determined conflicts between them. These conflicts were determined during the creation of the initial version of the QUEST use cases.

2.6 Trial design deport output

This document provides the description of the testing strategy needed for QUEST operational trials. Prior to focusing on the main parts of the QUEST trials, a brief overview of the agreed QUEST functionality is provided within this document.

After that, a list of the QUEST high-level use cases that describe the agreed QUEST functionality is introduced. Eight uses cases have been provided, each covering a specific QUEST functionality related to the different system conditions. Based on the use cases provided within this document, SE will write more detailed test cases. The intention of these test cases is to provide a possibility to prove that the implemented QUEST functionality covers all the agreements made during the QUEST design and QUEST objectives. These test cases will be written in the further phases of QUEST trial design and will provide a detailed step-by-step instruction and expected results for each step. In addition to test cases, which focus on the QUEST functionality, which will be written by SE, other partners (SGS, Fundamentals) will also provide a list of test cases that are related to their solutions (SGS's Cloud and Decentralised ANM systems and Fundamentals' SuperTAPP Relay). After all the test cases are provided, they will be merged to provide test cases that cover the whole cycle of QUEST's operation: QUEST functionality testing, sending commands to the devices in the field, the behaviour of all the voltage control techniques and ANM systems (including the external Cloud and Decentralised ANM systems) after QUEST performs the co-ordination actions.

After the use cases description, the testing phases timeline is provided. Pre-production and production QUEST environment are explained afterwards. Within this section it was mentioned that additional discussions related to the testing of QUEST and external ANM systems integration during the pre-production phase should be transitioned to the next phase of the QUEST trial design. At the end, the list of modelling studies needed to be performed by SGS prior to QUEST operational trials is provided.

Additional details of each individual trial and testing strategy of the QUEST system is in the QUEST Trial Design main document, published on ENWL's QUEST website.

2.7 Detailed site design overview

As part of QUEST, a total of 9 sites have been selected to have their AVC upgraded to the latest technology voltage control relay, SuperTAPP SG. SuperTAPP SG is approved as ENWL's standard voltage control relay and has been installed as BaU on any AVC upgrades completed on their network.

The 9 sites selected for upgrade within QUEST involve a mixture of BSP and primary substation sites fed out of Whitegate GSP. This means that all voltage control connected downstream of Whitegate GSP will be regulated by SuperTAPP SG equipment.

Fundamentals will also develop bespoke software algorithms to enable QUEST functionality on all SuperTAPP SG relays. Fundamentals have conducted site surveys at each of the 9 sites and have used their knowledge and expertise to make recommendations on the AVC upgrade works required for each site.

The 9 sites requiring AVC upgrades as part of this project are as follows:

- Ancoats North 100601 (T11/T12/T14)
- Greenhill Primary (T11/T12/T13)
- Chadderton BSP 301101 (GT1/GT2)
- Cannon Street 100607 (T11/T12/T13)
- Werneth 303300 (DNP3) (T11/T12)
- Greenhill BSP 300024 (GT2/GT3)
- Newton Heath 100624 (T11)
- Royton BSP 300009 (GT1/GT2)

- Redbank BSP 100503 (GT2/GT3)

This gives a total of 20 AVC schemes to be upgraded/installed.

2.8 Detailed site design report output

There were 16 site surveys completed in total in December 2021 over a 2-week period (9 full AVC upgrade sites and 7 feeder monitoring sites). For the full AVC upgrade sites, each survey took approximately 3 hours to complete.

Each site survey was completed by a Fundamentals project engineer accompanied by an ENWL Senior Authorised Person (SAP). Fundamentals bespoke AVC Upgrade Site Survey form was completed for each site and the findings shared with ENWL indicating advisories for AVC upgrade with QUEST functionality. Each site survey involved detailed recording of information, pictures of the site and equipment, cable run measurements, location of new AVC wall boxes and investigation into AVC drawing availability on site.

The Fundamentals design team will use all of the information gathered within the surveys to complete the new QUEST AVC design reports. Existing ENWL AVC related drawings required for modification will be requested from the ENWL. Full design packs for each site will be sent to ENWL for approval before commencement of installation works.

Summaries of each of the site surveys and reports can be found in the main QUEST Detailed Site Design document, published on ENWL's QUEST website.

3 NEXT DELIVERABLE (SYSTEM DESIGN AND TECHNOLOGY BUILD LESSONS LEARNED)

The next deliverable within this project is QUEST Interim Report – System Design and Technology Build Lessons Learned, which will run from 1 July 2022 to 30 June 2023. This deliverable will build on the success and learnings achieved in the last three deliverables to provide;

- QUEST software development and testing
- Power system model development
- Site installation for the voltage control and ANM equipment

The workstreams within this deliverable will be continued into the next deliverable. SE will lead on the QUEST software development and testing in continuation of their work on the QUEST architecture functional specification. SGS will lead on the specification for power system model development in continuation of their work on the functional specification for voltage control methodology. Fundamentals will lead on the site installation for the voltage control and ANM equipment workstream in continuation of their work on the QUEST detailed site design installation.

This workstream structure will be used to deliver the System Design and Technology Build Lessons Learned deliverable, as it provides continuity of work for project partners, helping to ensure consistency of work moving forward. ENWL will provide governance on all workstreams to ensure they are progressing as per the project time frame and to ensure the workstreams adhere to the overall project objectives.

4 CONCLUSIONS

- The work carried out within the four workstreams of this summary report meets the requirements set out within the QUEST Trial, Design and Specification deliverable. It builds on the research and learnings within previous deliverables to provide full functional specifications for the chosen architecture and voltage control methodology, in addition to outlining the trial design test strategy and detailed site design specifications. This was achieved by conducting a thorough review of the QUEST use cases and architecture options, developed in the first and second deliverables, and conducts in-depth analysis of the network model to provide understanding of which design meets the functional scope of the chosen architecture and voltage control methodology. This analysis and research will feed into the QUEST Interim Report – System Design and Technology Build Lessons Learned, the next project deliverable.

- NEM, one technique integrated within the QUEST architecture, will increase the 33kV network efficiency whenever possible by increasing the voltages on the 33kV distribution network. Hence not only will QUEST co-ordinate all voltage techniques on the network when required to ensure system is operating at optimum, it will also look to reduce demand when these systems are not in operation, to provide benefits to ENWL customers.

- QUEST will enhance the current functionality within the CLASS system as follows:

  - CLASS scheduling functionality enhancements
  - Introduction of the additional levels of demand reduction (¼ - demand reduction (DROQ) and ¾ - demand reduction (DRTQ)
  - BSP TSF

  The above functionality is not currently available within the CLASS system and is being introduced due to the QUEST development. These enhancements will further optimise voltage techniques on individual systems and reduce demand on the network. Further details on the above enhancements can be found in the QUEST functional architecture specification workstream report.

- The proposed architecture and voltage control functional specifications for QUEST system will improve each individual voltage technique key performance indicator, such as demand reduction, system loss reduction, reducing carbon emissions, etc. However, certain technique objectives fulfilment can reduce the overall impact of benefits, and in some case reverse them. Therefore, these benefits must be weighed against the limitations on a case-by-case bases. The QUEST system will allow the operator to configure the priority of each individual system and also provide visibility of the output of these configurations. This is the main purpose of the QUEST Contention Management Process (CMP) and QUEST Profile Editor, as seen within the QUEST user interface dashboard.

5 DEFINITIONS AND ABBREVIATIONS

Term	Definition
ADMS	Advanced Distribution Management System
ANM	Active Network Management
AVC	Automatic Voltage Control
BSP	Bulk Supply Point
CFOM	CLASS Forecast and Optimise Mode
DER	Distributed Energy Resource
DERMS	Distributed Energy Resources Management System
DB	Demand Boost (CLASS Function)
DBF	Demand Boost Full (CLASS Function)
DBH	Demand Boost Half (CLASS Function)
DR	Demand Reduction (CLASS Function)
DRF	Demand Reduction Full (CLASS Function)
DRH	Demand Reduction Half (CLASS Function)
DNO	Distribution Network Operator
EAVC	Enhanced Automatic Voltage Control
ENWL	Electricity North West Ltd.
ESO	National Grid Electricity System Operator
GSP	Grid Supply Point
GUI	Graphical User Interface
HV	High Voltage (refers to ENW 6.6kV and 11kV operating voltages)
NMS	Network Management System
OLTC	On-Load Tap Changer
PSP	Primary Supply Point
SE	Schneider Electric
SFR	Secondary Frequency Response (CLASS Function)
SGS	Smarter Grid Solutions
TS	Tap Stagger (CLASS Function)
UI	User Interface
SMST	Smart Street