# QUEST
# An overarching control system

electricity north west
Bringing energy to your door


QUEST Interim Report – System Design & Technology Build Lessons Learnt

Issue: 1

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Project Partners

nationalgridESO FUNDAMENTALS Schneider Electric

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## Approval

| Name | Role | Signature & date |
|---|---|---|
| Andrew Howard | QUEST Project Manager | AJ Howard<br>29 June 2023 |
| Victoria Turnham | Head of Network Innovation | Victoria Turnham<br>Digitally signed by Victoria Turnham<br>Date: 2023.06.29 15:39:37 +01'00' |

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# Glossary

| Acronym | Description |
|---|---|
| **ADMS** | Advanced Distribution Management System |
| **ANM** | Active Network Management |
| **AVC** | Automatic Voltage Control – the systems that regulate system voltage at the transforming points on ENWL network |
| **BaU** | Business as Usual – refers either to business-as-usual deployment of QUEST following successful trials or current process impacted by QUEST |
| **CB** | Circuit Breaker |
| **CI** | Customer Interruptions |
| **CID** | Curtailment InDex- Refers to the permissible amount of curtailment applied to a DER before DNO incurs penalty, the exact amount of which is laid out in the connection agreement. |
| **CML** | Customer Minutes Lost |
| **CT** | Current Transformer |
| **DER** | Distributed Energy Resource |
| **DERMS** | Distributed Energy Resources Management System |
| **DG** | Distributed Generation |
| **DBF** | Demand Boost Full (CLASS Function) |
| **DRF** | Demand Reduction Full (CLASS Function) |
| **DNO** | Distribution Network Operator |
| **DNP3** | Distributed Network Protocol 3 |
| **EMS** | Energy Management System |
| **ENWL** | Electricity North West Ltd. |
| **FAT** | Factory Acceptance Test |
| **GSP** | Grid Supply Point |
| **ICCP** | Inter-Control Centre Communications Protocol |
| **IEC** | International Electrotechnical Commission standards |
| **IED** | Intelligent Electronic Device |

| Acronym | Description |
|---|---|
| **IIS** | Interruption Incentive Scheme - regulatory performance incentive scheme based on CI and CML |
| **ISMS** | Information Security Management System |
| **LCT** | Low Carbon Technologies |
| **LL** | Load limiting (CLASS Function) |
| **LOM** | Loss of Mains |
| **MOL** | Merit Order List |
| **MOMS** | Merit Order Management System |
| **NIST** | National Institute of Standards and Technology |
| **NMS** | Network Management System |
| **OT** | Operational Technology |
| **PFR** | Primary Frequency Response (CLASS Function) |
| **RBAC** | Role Based Access Control |
| **RTS** | Real Time Systems |
| **RTU** | Remote Terminal Unit |
| **SCADA** | Supervisory Control and Data Acquisition |
| **SE** | Schneider Electric |
| **SFR** | Secondary Frequency Response (CLASS Function) |
| **SGS** | Smarter Grid Solutions |
| **SIEM** | Security and Information Event Management |
| **SWBD** | Switch Board |
| **TSF** | Tap Stagger Function (CLASS Function) |
| **UI** | User Interface |
| **VT** | Voltage Transformer |

# Executive summary

This report is the fourth deliverable for the QUEST Network Innovation Competition (NIC) project which is being rolled out by Electricity North West Limited (ENWL) and its partners. The aim of this report is to provide a detailed update and lessons learnt on the System Design and Technology Build of the project to date.

It builds upon the previously delivered and published reports for the Quest project:

| | | |
|---|---|---|
| 1 | QUEST Initial Report - Use Cases. | 31/07/21 |
| 2 | QUEST System Design and Architecture Lessons Learned. | 31/12/21 |
| 3 | QUEST Trials, Design and Specification Report. | 30/06/22 |

The main objective of the QUEST project is to introduce a distribution network-wide, fully coordinated, overarching control system to manage and optimise voltages, with an appropriate balance between centralised and decentralised control hierarchy. In recent years, and in common with all UK Distribution Network Operators (DNOs), ENWL has introduced innovative voltage optimisation and voltage control techniques.

Whilst the project currently remains on track to meet its aims, objectives, and deliverables (as outlined within the full submission) significant additional design work has been required to ensure the implemented QUEST solution remains secure within the heightened cyber security threat to the UK Critical National Infrastructure. The main impact of this work is an increase in the risk that QUEST trials may not commence as planned. However, the planned start date is still viewed as achievable, and mitigation is available in the trial programme should further slippage occur.

This report, and the associated reports (QUEST Functional Specification, Quest Test Cases and FAT Final report & QUEST Lessons Learnt,) can be found {here LINK} and detail the lessons from the QUEST Software Factory Acceptance Testing (FAT), provides the project progress to date including lessons learned from:

- QUEST software development and testing
- Power system model development
- Site installation for the voltage control and Active Network Management (ANM) equipment

# 1 Introduction

## 1.1 Purpose of this report

The purpose of this report is to fulfil the deliverable from the QUEST Full Submission Application (ENWEN04): to publish a QUEST project Interim Report – System Design and Technology Build Lessons Learnt on the QUEST website by 30th June 2023.

It details project progress to date including lessons learned from:

- QUEST software development and testing
- Power system model development
- Site installation for the voltage control and ANM equipment
- And the IT infrastructure design required to meet enhanced cyber security requirements

## 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.

However, since the Russian invasion of Ukraine in 2022 the GB Electricity Industry has been asked to review its Information and Operational Technologies for an enhanced level of cyber risk.

Partly in response to world events in 2022 Cyber Risk is being re-evaluated. The OFGEM response to the ENWL ED2 submission with respect to cyber risks has resulted in a further review and response to all Information and Operational Technologies, driving the need for an enhanced level of security against the potential risks.

For the QUEST project this has resulted in a delay to the infrastructure design and build to support the project and minor additional costs for some of that infrastructure.

Cyber risk will remain an issue for the industry for several years and may cause further unexpected project changes. The programme impact of the changes to date is that the deliverable of a tested system in September 2023 for commencement of trials is at risk of slippage. With the mitigation in place September is still the most likely completion date, and a small element of slippage can be mitigated within the trials phase.

A new ENWL project manager was appointed in February 2023 following the departure of the previous incumbent The opportunity was taken to hold a in person Partner workshop to support a smooth transition and to allow full project review to be conducted.

The Quest project supported two papers presented at the recent CIRED 2023, International Conference & Exhibition on Electricity Distribution held in Rome on the 12 - 15 June 2023. These papers where:

10291 QUEST - An Overarching System Control Solution

10295 Voltage Demand Relationship Modelling for Future Energy Scenarios

## 1.3 System design and technology build and lessons learnt

This report is the 4th project deliverable and builds on the previous reports.

| Ref | Project Deliverable | Deadline | Evidence |
|---|---|---|---|
| 1 | QUEST Initial Report - Use Cases | 31/07/21 | Document introducing the Project and detailing the use cases and scenarios. |
| 2 | QUEST System Design and Architecture Lessons Learned | 31/12/21 | Document explaining Project progress including the following outputs:<br>Review of architecture options<br>Specification for the network models and modelling regime |
| 3 | QUEST Trials, Design and Specification Report | 30/06/22 | Document explaining Project progress including the following outputs:<br>• Functional specification for chosen architecture<br>• Functional specification for voltage control methodology<br>• Trial design<br>• Detailed site design |
| 4 | QUEST Interim Report - System Design and Technology Build Lessons Learned | 30/06/23 | Document detailing Project progress to date including lessons learned from:<br>• QUEST software development and testing<br>• Power system model development<br>Site installation for the voltage control and ANM equipment |
| 5 | QUEST System Integration Lessons Learned Report | 30/12/23 | Document detailing the lessons learned from the installation and commissioning of the QUEST system including system integration and the results of site acceptance testing. |
| 6 | Customer Research Findings Report | 31/10/24 | Document detailing the outputs from the customer research. |
| 7 | QUEST Trials and Analysis Report | 30/12/24 | Document detailing:<br>• Final results from network trials<br>• Final results from modelling trials |

| Ref | Project Deliverable | Deadline | Evidence |
|---|---|---|---|
| | | | • Output from the voltage demand relationship research<br>• Any adaptation required to voltage control methodology |
| 8 | QUEST Final Report | 30/04/25 | Report on the conclusion of the QUEST Project including all the lessons learned and detailing the next steps, including BaU transition. |
| 9 | Comply with knowledge transfer requirements of the Governance Document. | End of Project | Annual Project Progress Reports which comply with the requirements of the Governance Document.<br>Completed Close Down Report which complies with the requirements of the Governance Document.<br>Evidence of attendance and participation in the Annual Conference as described in the Governance Document. |

### 1.3.1 QUEST software development and testing

Building on the "System Design and Architecture Lessons Learnt" the project has continued to develop the detail required for the delivery of the required QUEST overarching software. Through this process we have taken the project objectives, developed a series of Use cases, refined those further into a functional specification. Against this function specification the software has been developed in parallel to developing a series of test cases and ultimately a set of detailed test scripts to confirm that the delivered software meets that full hierarchy of requirements. The approach builds on the standard software development practise in place for all of ENWL NMS software development projects. As part of this process previous decisions can be refined, enhanced or corrected as appropriate, resulting version-controlled updates to earlier documents.

During a 6-day period in April ENWL, with support from Schneider Electric, performed a successful Factory Acceptance Test (FAT) of the designed software, with only minor non-conformities raised for resolution by June 23. The FAT scripts will form the basis as the Trial system is built and tested prior to final System Acceptance Testing (SAT). The FAT scripts will also be utilised to test all functionality in the early phases of Trial period.

The following associated documents have been published alongside this work:

1. QUEST Functional Specification. This document provides the detail of the QUEST overarching software. It provides an overview of requirements, plus detail on each of the required functions, the logic behind the requirement and, where appropriate, screen shots of the developed software that delivers the requirement

2. QUEST Test Cases and FAT Final Report. This lists the suite of 64 test scripts used to confirm the software meets the functional specification and hence the projects requirements. It also includes the result of each test. Whilst 6 of the 64 tests where failed, the failures where minor nonconformities and are easy to resolve. The level of non-conformity at this stage reflects a very successful test outcome. The minor nonconformities from the FAT include:

- Text adjustments and summation logic displayed in yield summary and elsewhere
- Detail on values on a signal point and exact interpretation by relay software
- Functionality correct, but text messaging incorrect
- Correct restore to normal post one test
- Test script correction to match Function spec and user requirement

3. QUEST Lessons Learnt Report. This document provides a review the FAT process including several discussions refining and redefining product requirements, operational logic and practical applicability of the software during the projects trial period. It identifies seven lessons learnt which can be categorised into the following groups:

- Improvements to the look and feel of the software interfaces
- Improvements to automate certain project manual functionality, should QUEST be transitioned to a BaU solution
- Future improvements to optimisation software should other changes to existing hardware functionality be developed
- Simplification of and ongoing review of initial software settings during trial, and potential changes for a BaU solution

### 1.3.2 Power system model development

The power system model development has previously been reported in the Modelling Regime report published in December 2012 and the Functional Specification for Voltage Methodology and Scenario Analysis report published in June 2022.

This work delivered a modelling regime for the network to be used for the QUEST trials, on which a series of scenarios could be analysed to predict how this network will respond in detail prior to real network trials. As well as confirming the concepts behind QUEST it has also informed expected responses for QUEST trials.

Several outputs from the modelling have been used as configurations within the QUEST overarching software referred to in 1.3.1 and the supplementary document

### 1.3.3 Site installation for the voltage control and ANM equipment

The core site installation works, fitment of QUEST compatible voltage control equipment at Grid and Primary substation and replacement of distribution transformers with on load tap changers (OLTC), have been completed early as suitable resources had become available and the opportunity to reduce delivery risk taken. One exception is a single distribution OLTC transformer site which has been replanned for July 2023 due to site construction constraints. The revised software for the Grid and Primary Automatic Voltage Control (AVC) relays was delivered to ENWL in June 2023. This software will be tested on an ENWL Network Management System (NMS) test system before being uploaded into the production AVC systems on site ready for final system testing and start of trials. The testing and roll out of the relay software is following ENWLs standard practise for this type of change where

changes can be tested locally, then within a secure test system before being installed on site. This minimises the risk of unforeseen impacts to ENWL customers.

The Smarter Grid Solutions ANM (cloud and decentralised) systems (software) has been built and tested on SGS infrastructure. This will be loaded onto IT hardware in the ENWL data centre in July 2023 (see below).

### 1.3.4 IT infrastructure – design, approval, and installation

The increased threat faced by the UK and its critical national infrastructure has had a significant impact to the detailed IT infrastructure design, both in its complexity and in the resources required to approve and deliver it during a major review of all ENWL critical IT infrastructure. The cyber risk QUEST poses is that to conduct live trials it must integrate with the production NMS to allow the control of transformer voltage control equipment feeding real customers. At the same time the QUEST overarching software is project functionality and therefore not fully integrated into the core NMS, and it also needs to communicate with other partner supplied systems which can be considered potential attack vectors.

The current detail design allows the project's QUEST overarching software control to sit on independent hardware within a secure space in the ENWL data centres. Limited connections Inter Control Centre Protocol (ICCP) can then be made to the ANM (cloud & centralised) services provided by SGS and a connection made to the ENWL NMS (test and production). [Note: ENWL NMS has three key environments, Production is the real time system, Test is a replica system where changes can be tested before release into production, and Development where future changes and enhancements can be developed].

Through this connection into the NMS production system, the QUEST overarching software will take control of the real-world voltage management systems installed on the Whitegate Grid Supply Point (GSP) network, during the active trial periods. The design should prevent any illegitimate access back through the QUEST Project infrastructure into the production NMS. When not in use, many of the inter system links will be restricted to further reduce any opportunity of attack.

# 2 Lessons learnt

## 2.1 IT infrastructure – design, approval, and installation

The project risk log includes two items that have had an unforeseen interaction.

- Original Bid: Technology - There is a risk that the final architecture design may be more complex than originally anticipated leading to an increase in cost and delivery timescales.
- Raised December 21: Cyber Security - Integration of SGS ANM within ENWL NMS system have issues to cyber security requirements

The project could not have predicted change in Global security and the national response to the resultant change in the cyber threat to the UK. The required changes for the project have been delivered through a detailed low level IT architecture design.

The low level design has been led by ENWL IT teams, and the solution is compliant with ENWL enhanced security processes. The established good project relationships have been utilised to identify a suitable solution to minimise the potential impact to the project timeline and budget

The main high-level changes have been:

- The hardware on which the QUEST overarching software resides has been decoupled from the core production NMS systems to protect that critical infrastructure from potential threat opportunities the project development work could introduce.
- This decoupling also has the advantage of separating the development work from some of the system hardening and testing process of the critical systems.
- The decoupled QUEST system still interfaces with and controls through the critical production system, but this is now through an easier to secure ICCP link.
- ICCP links are also in place to allow integration with the SGS supplied ANM systems, with the security level of the links matching the risk of that connection.
- The hardware supporting the project is physically located within ENWLs corporate data centres.

## 2.2 QUEST software development and testing

Also published with this report are the three associated documents authored by Schneider Electric and linked to in section 1.3.1. These provide more detail on how the previously published use cases and system design have evolved and been refined into a detailed functional specification against which the software has been built and tested against using processes consistent with core NMS product development.

A significant part of the document covers lessons learnt from the software FAT with many "enhancements" identified. Should, as a result of this project, QUEST prove successful these enhancements would be considered as part of a transition project embedding QUEST overarching software within the core network management system code.

Examples of enhancements include automating a manual business process / setting to be used in trials, increasing the resolution of outputs available for optimisation, other advances in on site technologies that could be adapted by QUEST.

It is expected the period of trials will confirm or refine some of these lessons with practical experience.

The development process for detailed software development, starting with use cases, has allowed a clear definition on what functionality is to be delivered and how it should work. However, a subsequent review identified that the benefits calculated from the functionality and the varied mixes of optimised responses, could be better communicated to the user. Further refinements where then made, and incorporated into the final functional spec, to create a Yield Summary report. This is a reporting tool providing benefits by service type for the mix of responses requested. Section 4.5.QUEST Dashboard of the associated document QUEST Functional Specification provides further detail on this reporting, and the FAT process identified additional refinements to improve user interpretation of results presented.

## 2.3 Power system model development

Most of the lessons learnt regarding the power system model have previously been reported, however outputs from those models have been used in calibrating and initial settings used in the optimisation

software. For example, a number of power application settings documented in the associated document, Functions spec section 5. METHODOLOGY.

The previously reported work on power system modelling has been encompassed within the developed software. The modelling has set an expectation on how the network will respond under a range of scenarios and this has informed a series of configurable default values and settings within the software. These values can be reviewed based on real world performance.

## 2.4 Site installation for the voltage control and ANM equipment

The QUEST project has benefited significantly from the business processes and partner relationships developed across previous projects including CLASS and Smart Street.

No additional lessons have been learnt from the site installation work. Much of the work has followed procedures established during the CLASS and Smart Street installation phases. We have experienced just the routine issues from working on an operational network and working on distribution assets physically located in the vicinity of our customers homes.

# 3 Next steps

The next 3 months are critical to the project where significant work still needs to be delivered in order to commence trials as planned, accommodating the required cyber changes. The remaining IT hardware build on ENWL premises will be completed to the approved low-level design, the software developed by SE and SGS will be deployed and tested. ICCP links will be introduced in a staged manner to link and test interfaces. This process is being done in both ENWL NMS support and production environments to minimise risks to our core systems providing the day to day service to our customers.

In parallel the new AVC software provided by Fundamentals will be tested using ENWL Business as Usual (BaU) processes and systems, before being rolled out onto site devices.

Final checks will then be performed using ENWL NMS BaU support systems prior to a final complete system site acceptance testing including control of on-site equipment supplying our customers.

Commencement of live trials can then commence.

# 4 Conclusions

The work completed and reported within this report meets the requirements set out within the QUEST deliverable. It builds on the work performed and reported on to date.

The low-level IT architecture design has been heavily influenced by the increased cyber security risk now in place, that all GB DNOs have had to and continue to respond to as critical national infrastructure.

Despite these changes, the overall architecture remains consistent with that reported previously and with the QUEST full submission (appendix B) The physical hardware separation required for the project to meet current risk standards, would change should QUEST be adopted into core code. As core code it would be subject to the same rigorous security standards and processes required for core systems, and also be subject to significantly more change and integration testing from any other changes within the core system.

The time and effort to meet the enhanced cyber risk, has increased the risk to the completion of the implementation phase and the start of the trial phase. However appropriate resources are in place to complete planned works, and additional facilitation between key resources is also in place to quickly identify and respond to any further emerging risks and issues.

The QUEST software has passed FAT and has been shown to meet the user case / project requirements.