Slide Pack from 10 December Dissemination day

SP Electricity North West

SP ENW Website	All the projects output have and will be published at: https://www.enwl.co.uk/future-energy/innovation/key-projects/quest/
SP ENW Innovation Team	Contact us at: InnovationTeam@enwl.co.uk

SP Electricity North West

SP Electricity North West

QUEST Dissemination Day 10th December 2025

Innovation

10/12/2025

Welcome

Welcome – QUEST Network Innovation Project Dissemination Day

Basics

– Safety Moment

  – Fire Alarms –

  – Fire Exit –

  – Breaks – Drinks and Snacks in breakout area

  – Lunch – Deli Buffet Served in breakout area

Welcome from Neil McClymont – Head of Innovation Strategy

Running Order for the Day

Welcome from Neil

Neil McClymont

Head of Network Innovation
SP ENW

Aim for the Day

SP Electricity North West

Refresh – Why and What did we set out to do

Inform – Why are we confident with our findings

- The What and How of what we did
- Supported by our project Partners

Learn - What lessons can we take, to make future innovation better

Use - What are SP ENW plans to use QUEST in future (and issues therein)

OVERARCHING CONTROL SYSTEM QUEST

What is Quest

Quick Introduction into the Project:

QUEST Explained

SP Electricity North West

QUEST - £7.95m NIC project awarded November 2020.
Due to run April 2021 to April 2025 but delayed (December 2025).

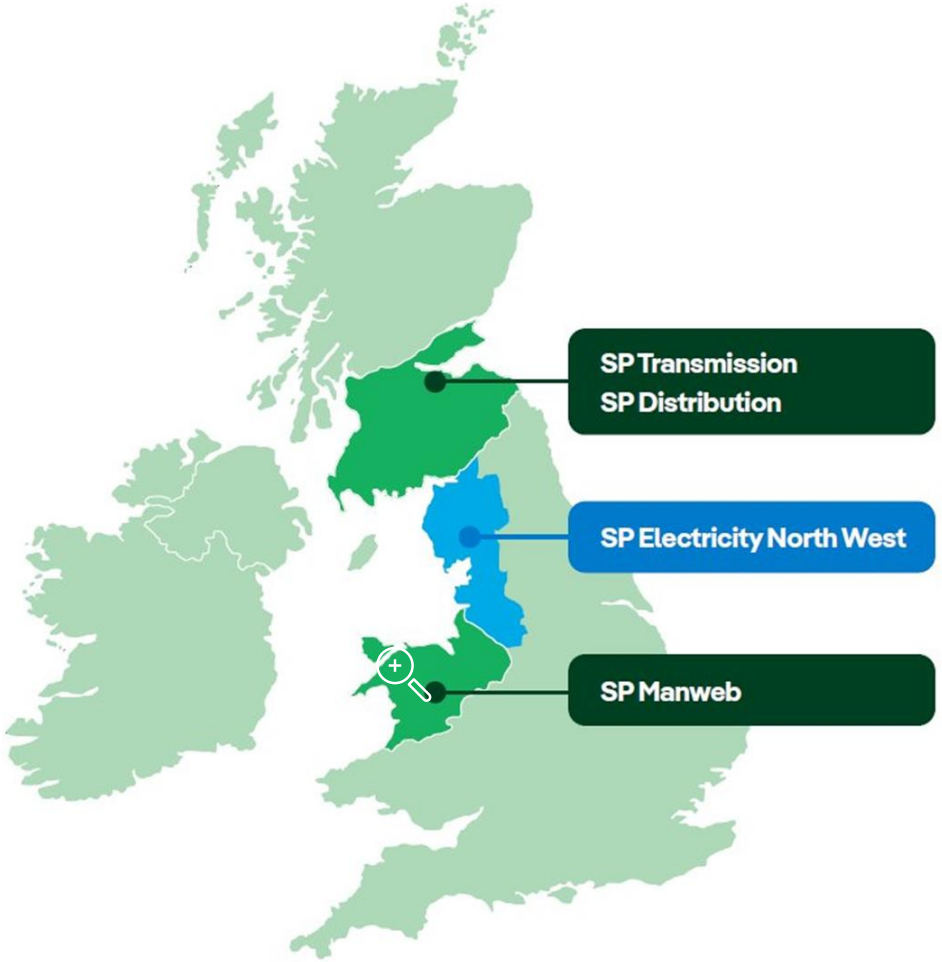
QUEST is a whole-system voltage optimisation system, comprising software held centrally within a network management system, alongside intelligent devices fitted in substations.

QUEST will co-ordinate the actions of multiple voltage control and optimisation techniques, including CLASS, Smart Street and Active Network Management (ANM), holistically across the whole system to optimise their use and facilitate the increased use of Low Carbon Technologies (LCTs).

Why is QUEST Needed?

QUEST demonstrates active Voltage Control across all of the DNO network voltages can be optimised to maximise the use of the existing network and allow for the increased uptake of LCTs and the subsequent increase in demand on the network.

DNOs have deployed several discrete voltage management techniques to manage the networks. QUEST will address their inherent limitations by fully coordinating their use.



Schneider Electric FUNDAMENTALS smarter grid solutions NESO National Energy System Operator IMPACT FROM INSIGHT TO INFLUENCE

QUEST Partners

SP Electricity North West

Schneider Electric	FUNDAMENTALS	smarter grid solutions	NESO National Energy System Operator	IMPACT FROM INSIGHT TO INFLUENCE	
Developer of QUEST overarching software Also Provider of SP ENW Network Management System (Build and Support of part of the QUEST IT Infrastructure) Supporting the rest of the project	Developer of enhancements for the Supertapp AVC relays Installation works at several BSP and Primary sites Update works at the remaining BSP and Primary sites Supporting the rest of the project	Provision of Whitegate Digital Twin and its use in QUEST development and assessment Provision of Two ANM system to replicate both DER and aggregator Supporting the rest of the project	Overview of System control and impact of the network interface the grid Supporting the rest of the project	Customer engagement Do Customer notice Voltage Management? How to engage EHV and HV customers on Voltage Management issues Interest in Voltage managed contracts with EHV and HV customers Supporting the rest of the project	SP ENW IT – Infrastructure& ICCP Design, Build, Change Management, Support OT - Telemetry Hub/Control – Trials and Analysis Ops – Site Works Ricardo – External Project Assurance

The Project

Innovation Funded
Now Business as Usual

SMART STREET

Innovation Funded
Now Business as Usual

CLASS

New Innovation
132/33 kV QUEST element

OVERARCHING CONTROL SYSTEM QUEST

OVERARCHING CONTROL SYSTEM QUEST

- New Distribution OLTC Install (Smart St standard) & access to existing units
- Additional CLASS response steps
- Upgrade to 33/HV Voltage Control systems
- Application of enhanced 33/HV solution to 132/33 system
  - First time functionality at this Voltage level
- New QUEST Overarching Control System software
  - Full Control at all Voltage levels below Whitegate Grid Supply Point
  - Optimise / maximise voltage control at each voltage level
  - Interface with other elements of Network Management e.g. ANM, Emergency situations
  - Development of Digital twin – to inform and corroborate results

QUEST – It does what it says on the tin !

QUEST can control voltage at all Network Levels

QUEST can optimise voltage across all levels based on priorities set

QUEST will maximise benefits, once all priorities have been met

QUEST can integrate with 3rd party customer systems and modify their operation

QUEST benefits can be verified against modelling with a digital twin model

QUEST can do this using standard SP ENW network equipment

OVERARCHING CONTROL SYSTEM

QUEST

Agenda

SP Electricity North West

Topic	Presenter	Time
Start & Welcome	SP ENW	10:00 - 10:10
Introduction	SP ENW	20 min 10:10 – 10:30
What we did with Our customers Money		10:30 – 14:30
SP ENW Overview	SP ENW	20min 10:30 – 10:50
10 Min Comfort Break		10:50 – 11:00
SGS “Provider/ANM” & “Research/Digital Twin”	SGS	50 min 111:00 – 11:50
Fundamantals Installations	Fundamantals	20min 11:50 – 12:10
Lunch		12:10 – 12: 50
SE Software Development. Use Cases to testing & debugging	SE	60min 12:50 – 13:50
Customer Engagement	Impact	20min 13:50 – 14:10
What we learnt		14:10 – 15:50
SP ENW Trials and Analysis	SP ENW	60min 14:10 – 15:10
10 Min Comfort Break		15:10 – 15:20
Project Partners	ALL	15:20 – 15:35
Formal Lessons	SP ENW	15:35 – 15:50
How are we going to use it	SP ENW	15:50 – 16:00
Closedown		16:00

What we did (Apr 21 – Jun 22)

- **Mobilised the project and started developing our first deliverable – The Use Cases (Jul21)**
  - Including Industry input, a documented approach refining the requirements of the project and providing a robust foundation for design, build and trails
  - 8 Use cases containing 17 specific issues to co ordinate
- **System Design and Architecture (Dec 21)**
  - Modelling Regime – led by SGS
    - How could the use cases be modelled, controlled and applied against SP ENW network
  - Architecture Options – led by SE
    - Stress testing, refining and clarifying the published Use Cases
    - Developing architecture options on which to build the optimisation
- **Trials, Design and Specification (Jun 22)**
  - Choosing & documenting the functional specifications for the architecture, voltage control methodology, trial design and detailed site design

What we did (Jul 22 – Dec 24)

- **Planned Interim System Design & Technology Build – Lessons Learnt (initial) – June 23**
  - CYBER !
  - Design and Implementation changes to the IT Architecture and subsequent effects
  - On site works well ahead, Relay development complete (for testing), ANM built (@ SGS)
- **System Integration Lessons Learned Report – Dec 23, updated Apr 24**
  - CYBER ! (and subsequent wider impacts, impacts on QUEST)
  - BUT completed – Site Works, Relay works, Software tested (FAT and SAT on alternate hardware), ANM systems ready for ENWL hardware
  - Customer Area 2 HV & EHV consumer work completed
- **Project Progress Reports. Dec 23 & Dec 24**
  - Both reporting and quantifying the project delays, focussed around getting the revised IT built
    - June/July 24 – First IT Build complete
    - Issue finding and resolution still ongoing at year end

What we did (Jan 25 – Dec 25)

- **More Issue finding and resolution**
  - Inc hardware failure, licenses, false starts
- **Area 3 Customer engagement – Voltage managed connections**

- **TRIALS ! May 25 – Sep 25**
  - Available – System, Resources, Access (mostly)
  - Innovation and Control team together, Partner Support (often Real Time)
  - Starting Simple, Gaining complexity, adding in ANM systems
  - Addition system and access issues, influencing trial learning
  - Restarting Area 1 domestic engagement

- **Customer Research Findings Report – Sep 25**

- **Trials and Analysis Report – Nov 25**

10 Minute Comfort Break

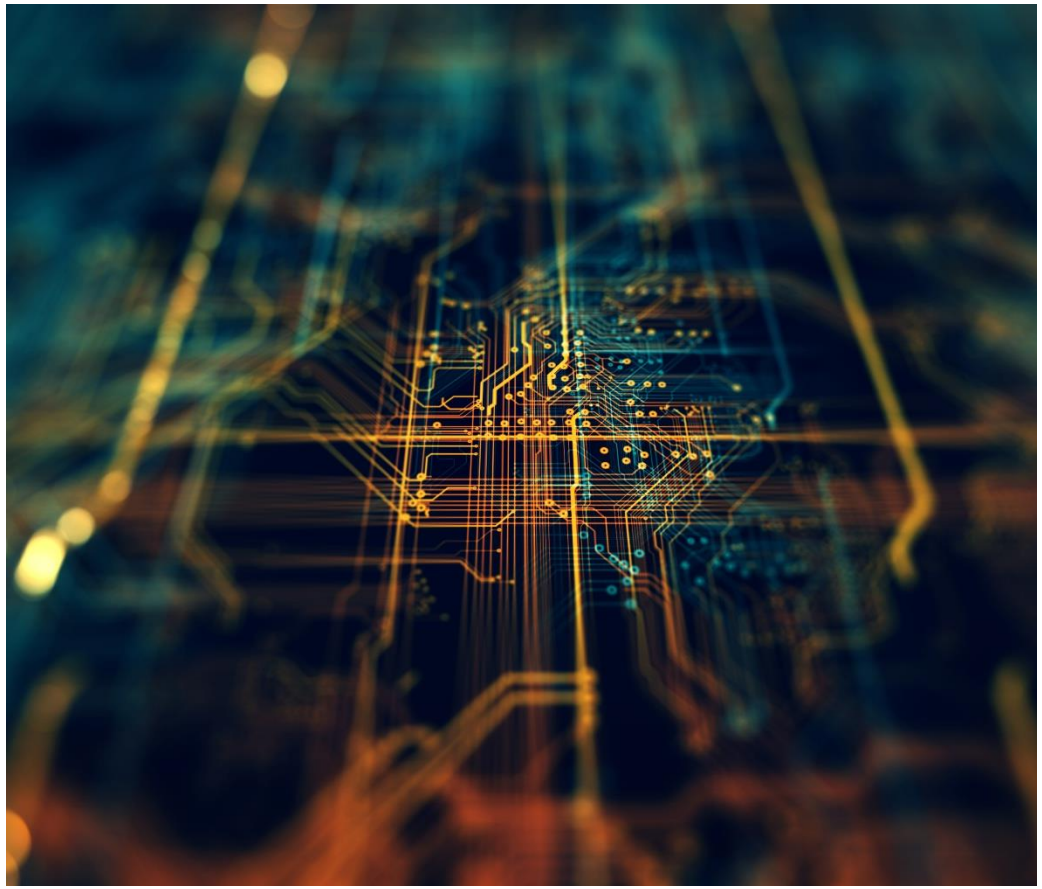
SP Electricity North West

smarter grid solutions

QUEST Dissemination Day
10th of December 2025

Agenda

1. Introductions
2. SGS Scope
3. Provider Scope – Project Progress Review
4. Research Scope – Project Progress Review
5. Lessons Learned
6. Celebrating Success



QUEST Dissemination Day Introductions

SGS Attendees

Robert MacDonald – EVP of Consultancy and UK Sales

Samuel Elisha – Senior Integration Engineer

David Conkie – Senior Smart Grid Consultant

Yunus Cem Duman – Smart Grid Consultant

Kiera J. Todd – Project Manager

QUEST Dissemination Day
Smarter Grid Solutions - Scope

SGS Provider & Research Scope

QUEST SGS Provider Scope

1. Configuration, integration and testing of a “Decentralised ANM” system for real-time DER control and constraint management
2. Configuration, integration and testing of a “Cloud ANM” system to enable flexible service dispatch via third-party aggregators
3. Development of interfaces with QUEST for coordinated voltage control
4. Support the design and trial development of the QUEST overarching control system

QUEST SGS Research Scope

1. Defined use cases and developed a modelling regime to support scenario analysis using network models
2. Built and configured the Digital Twin to simulate both testable and non-testable trial scenarios
3. Delivered the QUEST Trials & Analysis report and updated the business case and carbon benefits case based on findings

QUEST Dissemination Day
Smarter Grid Solutions – Provider Scope – Project Progress Review

Project Progress Review – Decentralised ANM

- Procurement of servers, RTUs and hardware panels for Strata Grid servers and ANM Outstations
- Build and testing of Strata Grid and ANM Outstation panels
- Strata Grid server build, software configuration, and Pre-Factory Acceptance Testing at SGS offices
- Strata Grid server build and software configuration on QUEST Pre-Production and Production environments
- Installation and commissioning of RTU panels
- Factory Acceptance Testing (FAT)
- ICCP set-up
- Pre-Production Testing (PPT) & Site Acceptance Testing (SAT)
- Decentralised ANM Health Check document issued and demonstrated to SP ENW
- Decentralised ANM User Guide & Decentralised ANM User Interface issued
- Live system tests
- SGS Support for the Decentralised ANM has finished on the 31/07/2025
- Made a final copy of the software on the servers & tidied up (delete files not needed etc.) to leave system in a clean state

smarter grid solutions

Project Progress Review – Cloud ANM

- Cloud ANM server build on AWS environment
- AWS/QUEST VPN configuration and testing
- Pre-Factory Acceptance Testing (FAT) and FAT completed
- Secure ICCP set-up with Schneider Electric (SE)
- Integration and testing of Cloud ANM optimisation and forecasting
- Demonstrations to SP ENW
- Live system tests
- SGS Support for the Cloud ANM has finished on the 31/07/2025
- Data was extracted and shared with SP ENW

Project Progress Review – ICCP Set Up

- Determination of Royton BSP **measurements, statuses, and control signals** to be monitored for ANM control
- **Licensing, set up and configuration** of SISCO AX-S4-ICCP link to Test QUEST Server on PST1 (Test) and Quest Server on PST2 (Production) environments
- **PPT testing** of ICCP data transfer between Decentralised ANM and QUEST server on PST1
- **SAT testing** of ICCP data transfer between Decentralised ANM and QUEST server on PST2

ICCP on Cloud ANM:

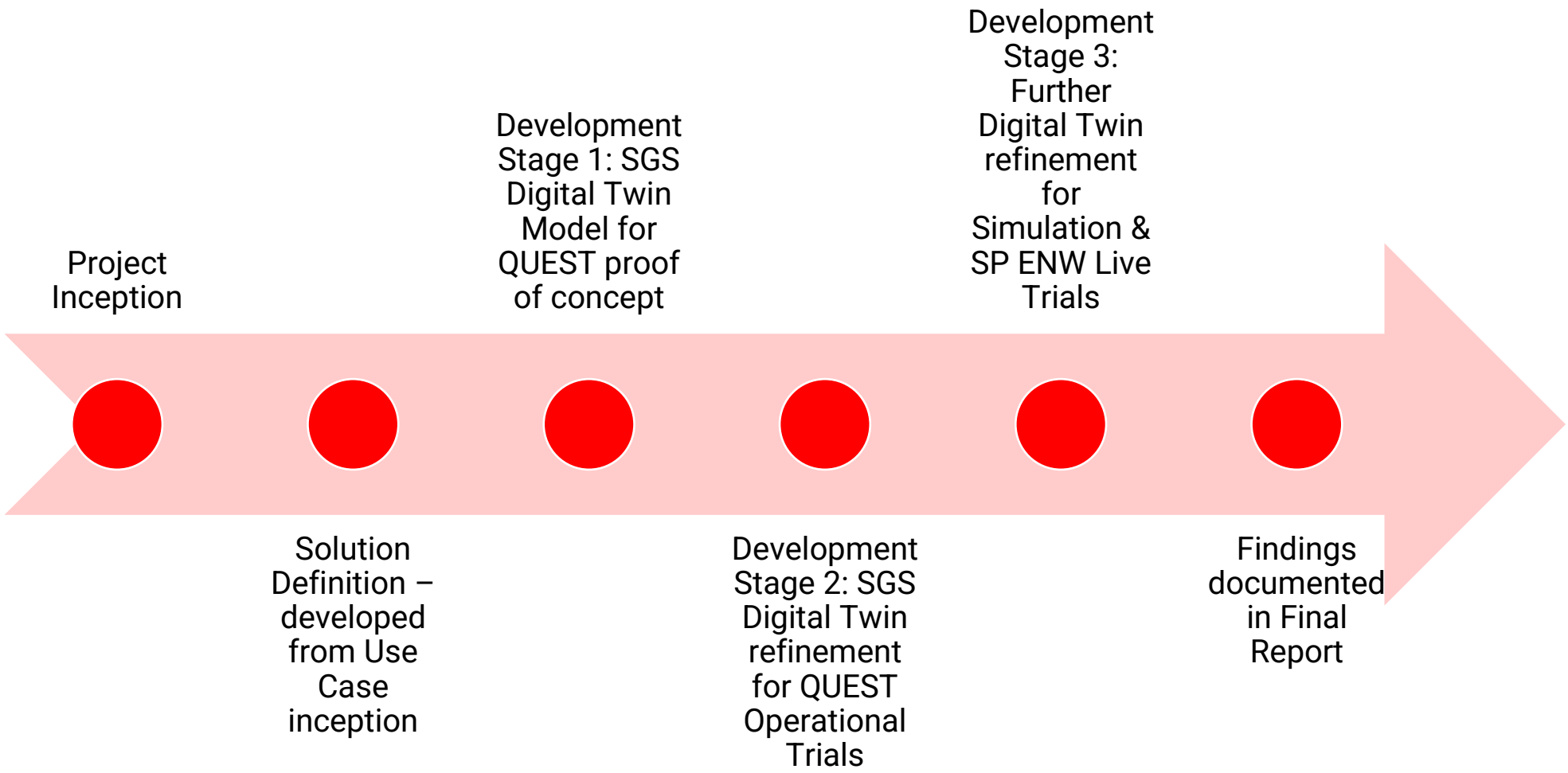
- **Installation, licensing, set up and configuration** of SISCO AX-S4 ICCP link between Cloud ANM server in AWS, and Quest Servers on PST1 and PST2 environments
- **AWS/QUEST VPN configuration and testing**
- **Testing** of ICCP data transfer between the SGS Cloud ANM server and QUEST system in PST1 and PST2 environments.

Project Progress Review – Other Completed Work

- **Integration and testing of Cloud ANM optimisation and forecasting** functionality
- Added **FSP (Flexibility Service Provider) simulation web application** to Cloud ANM
- **Determination and reconfiguration of MP threshold values** based on actual network measurements
- Created ANM User Accounts for SP ENW Personnel

QUEST Dissemination Day
Smarter Grid Solutions – Research Scope – Project Progress Review

SGS Research Scope Timeline



smarter grid solutions

QUEST Objectives

- *The main **objective** of the QUEST overarching software can be summarised as:*

  'Control and coordinate multiple operational systems and control method objectives operating upon the SP ENW network, whilst endeavoring to prevent conflicts between those systems and providing voltage optimisation where possible.'

- *This splits into three core operational objectives:*

  1. *Coordinate operation of system voltage control and optimisation systems,*
  2. *Identify and avoid potential conflicts between multiple systems, ensuring appropriate configuration of key voltage control and optimisation of systems where achievable,*
  3. *Enhance operational efficiency, by establishing novel additional techniques,*

- *To achieve these objectives a set of use cases was defined to support solution development*

Use Cases & Solution Definition

Use Cases

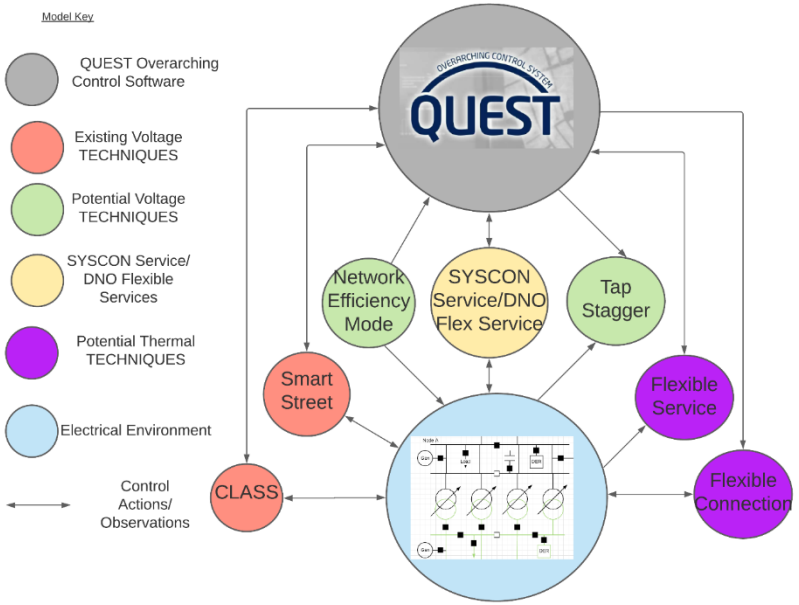
- The functional use cases identified to support development of the QUEST overarching Voltage Control System are listed below:
  - *CLASS*
  - *Smart Street*
  - *Tap Stagger*
  - *NEM*
  - *Flexible Connections*
  - *Flexible Services*
  - *NG ESO responses e.g. OC6, LFDD*
- For each use case how the QUEST solution intended to operate was developed for each individual use case and a set of blended use cases
- These Use Cases formed the foundational guide to define the solution

Solution Definition

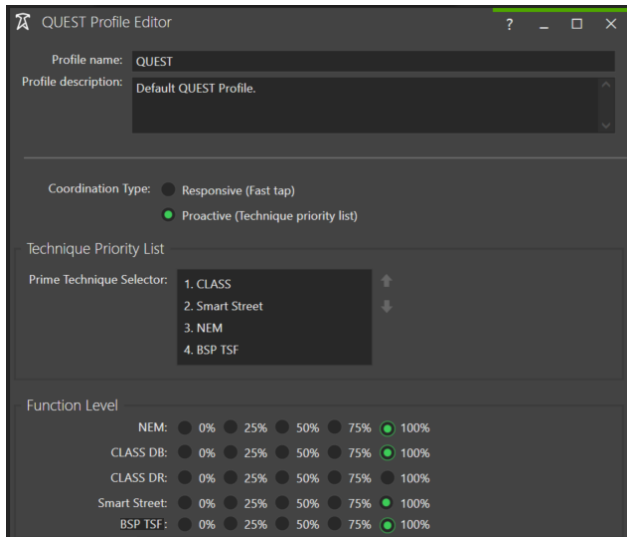
- A control method (derived from Use Case development) was created to achieve these objectives and deliver a converged control state (the QUEST state), applied to the electrical environment.
- To determine whether the QUEST control method can achieve its core operational objectives, a modelling regime was created that encapsulates:
  - *the existing and potential network control methods applied to SP ENW's network.*
  - *how these control methods are applied to a simulated SP ENW network,*
  - *and how these control methods are controlled and coordinated by the overarching QUEST software, identify the positive and negative impacts to operational efficiency and optimise the control methods to maximise operational efficiency.*

Development Stage 1: Initial Digital Twin Development & Proof of Concept Testing

- Development Stage 1: desktop modelling at low resolution
- The digital twin is a Quasi-Dynamic time-series based solution
- The QUEST control environment is emulated in Python and the electrical environment is simulated using a load flow model.
- The Digital Twin can manage the QUEST functions in different priority orders and at different function levels



QUEST High Level Architecture



Implementation of QUEST function levels & priority order

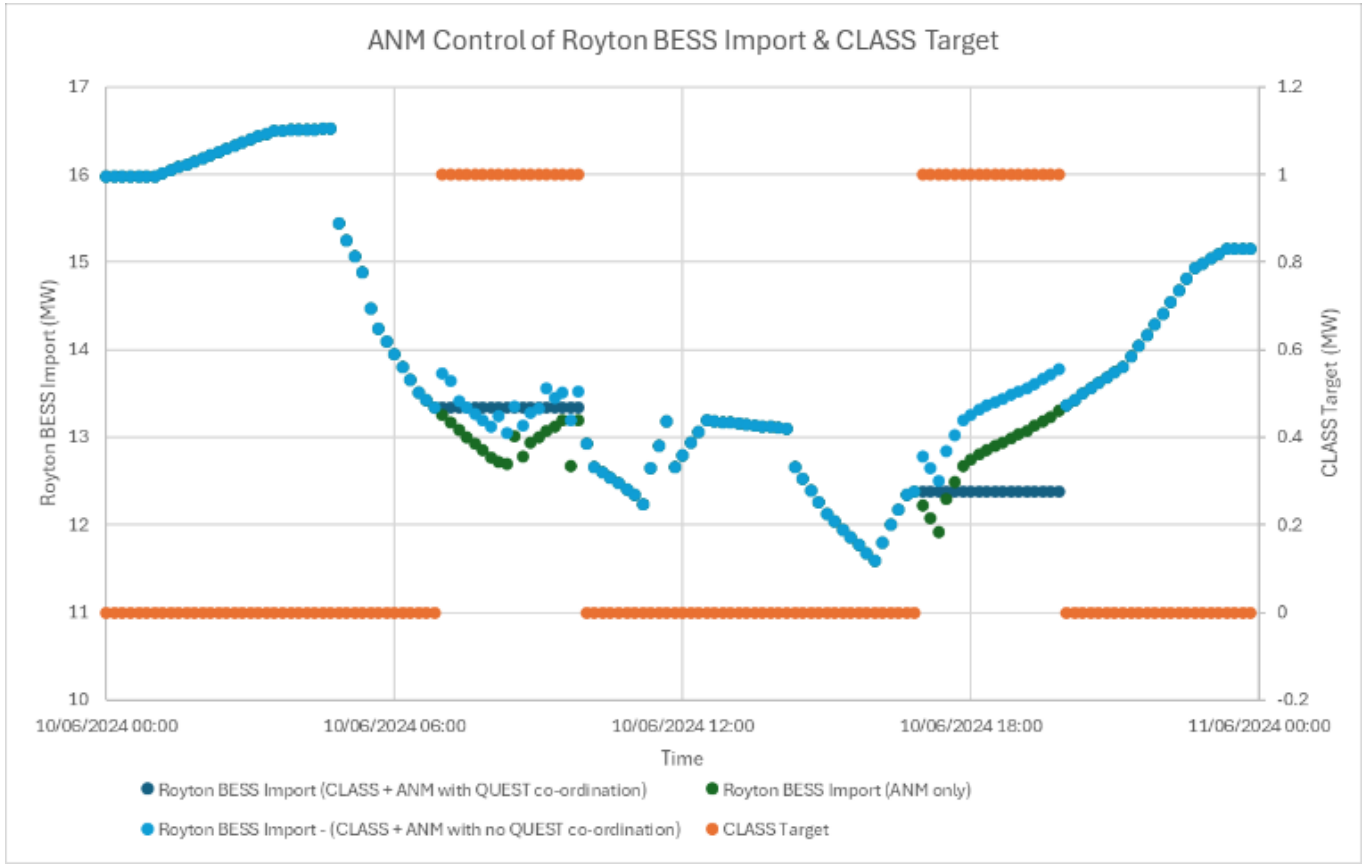
	Before QUEST applied	After QUEST applied	Difference
Total System MW Demand	79.06	82.606	-3.55
Total External Generation MW	83.40	87.03	-3.63
33kV Losses MW	0.1533	0.2334	-0.08
System Carbon ($kgCO_2$ Average)	7849.18	7960.49	-111.31
Total System MVAr Demand	1.55	3.83	-2.28

QUEST Results Extract from CIRED 2023 paper

smarter grid solutions

Development Stage 2: Digital Twin Refinement for Operational Testing

- Development Stage 2: Further testing was completed using desktop modelling with more function combinations being added and tested
- Examples of initial tests completed with measured loading data from the SP ENW network:
  - *CLASS Demand Reduction & Smart Street*
  - *CLASS Demand Reduction & ANM Flexible Connections*
  - *CLASS Demand Reduction & NEM*
  - *NEM applied for Voltage Constraint Management*
- These tests and results were included in our paper for CIRED 2025



Results Extract From CIRED 2025 Paper

smarter grid solutions

Development Stage 3: Further Digital Twin Refinement for Simulated & Live Trials

- Development Stage 3: Blended desktop & live system modelling using high resolution measured data to compare existing control methods and test emergency conditions

- Further refinement included greater alignment with the operation of the live SE QUEST functionality

- The purpose of the Simulated and Live Trials were to:
  1. Ensure the live system is functioning as expected - validating control methods and their conflict arbitration,
  2. Validate the performance of the SGS QUEST system model against the live SE QUEST system to ensure fidelity between the two systems,
  3. Test control methods that can't be assessed in live trials to satisfy fitness for purpose of the QUEST solution as a whole.

Simulated & Live Trials Set Up

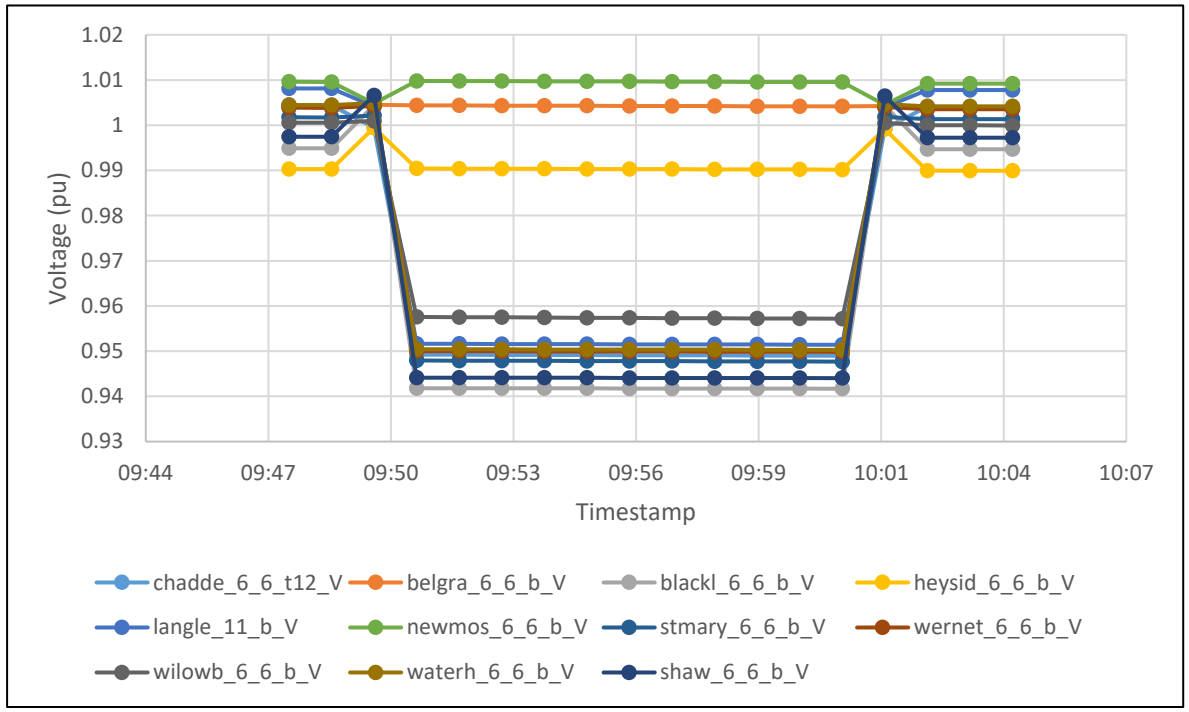
Trial Test Summary:

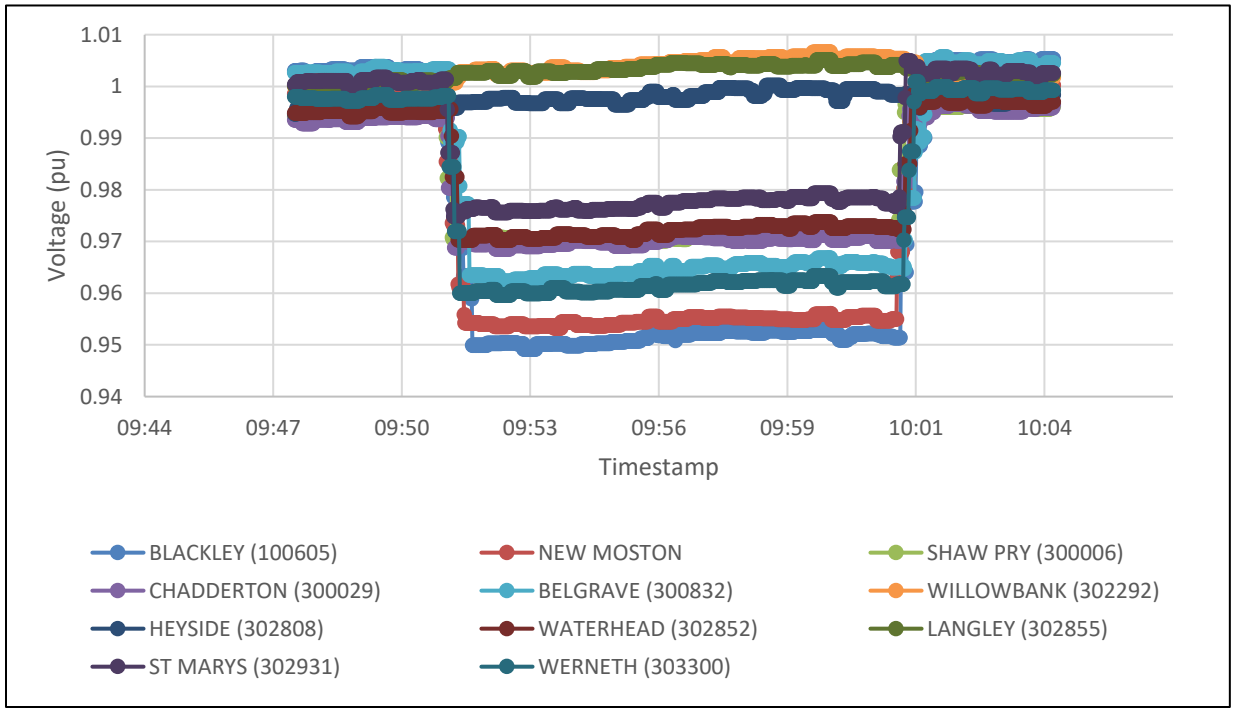
Test Number	Test Type	NEM Function Level/Priority	CLASS Mode	CLASS Function Level/Priority	Smart Street Function Level/Priority	OC6 Mode	LFDD	Tap Stagger
01	Live & Simulation	25/2	DR	25/3	25/1	N/A	N/A	N/A
02	Live & Simulation	N/A	DR	100/1	0/2	N/A	N/A	N/A
03	Live & Simulation	N/A	DR	0/2	100/1	N/A	N/A	N/A
04	Live & Simulation	N/A	DR	75/1	25/2	N/A	N/A	N/A
05	Live & Simulation	N/A	DR	25/2	75/1	N/A	N/A	N/A
06	Live & Simulation	100/1	DR	100/2	100/3	N/A	N/A	N/A
07	Live & Simulation	100/2	DR	100/3	100/2	N/A	N/A	N/A
08	Live & Simulation	100/3	DR	100/2	100/1	N/A	N/A	N/A
09	Live & Simulation	50/1	DR	25/2	50/3	N/A	N/A	N/A
10	Live & Simulation	N/A	DB	100/1	0/2	N/A	N/A	N/A
11	Live & Simulation	50/2	DB	50/1	0/3	N/A	N/A	N/A
12	Simulation Only	25/2	DR	25/3	25/1	VR/DD	N/A	N/A
13	Simulation Only	25/2	DR	25/3	25/1	N/A	ON	N/A
14	Simulation Only	N/A	N/A	N/A	N/A	N/A	N/A	ON

- Each trial test was configured with Function Levels & Priorities as per the table above
- Loading data during the live trial was provided by SP ENW, processed accordingly and used in the model

Simulated & Live Trial Comparison Example Results

Test 08 – Smart Street 100 + CLASS 100 + NEM 100 – 15/07/25

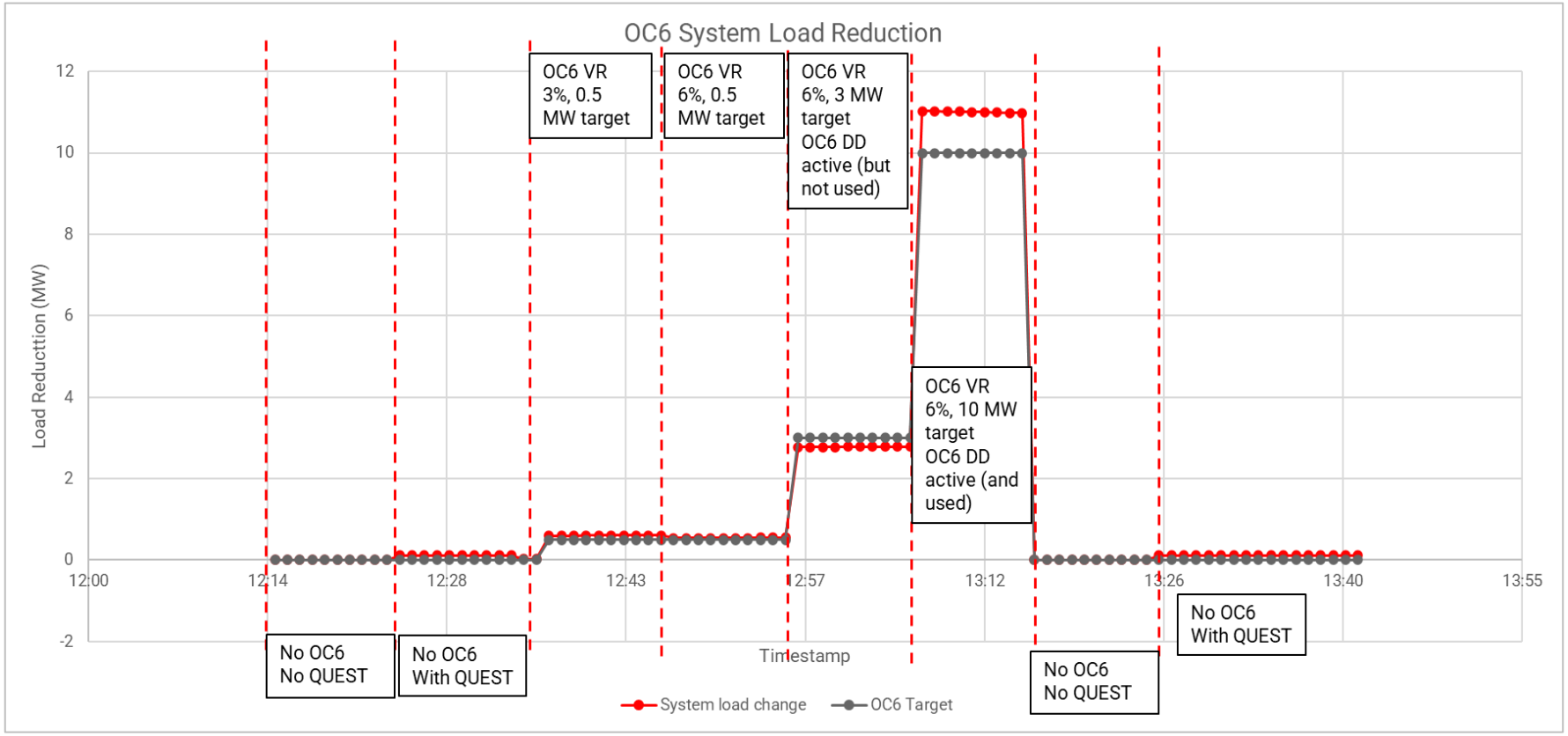




smarter grid solutions

Simulated & Live Trial Comparison Example Results

Test 12 – Smart Street 25 + NEM 25 + CLASS 25 + OC6 VR/DD



smarter grid solutions

Key Findings

- **CLASS:** CLASS results are broadly similar between the two systems, although the SGS QUEST system model often reports achievement of the CLASS demand reduction target when the live QUEST system has not. This is due to the electrical environment in the digital twin calculating lower voltages than what occurred on the live system.
- **NEM:** Results for NEM are broadly similar when there were no deviations from normal in the operational system.
- **Smart Street:** Results for Smart Street were more difficult to compare:
  - *Not all the Smart Street site data was available to be graphed, and some data was only available at 10-minute intervals,*
  - *Some secondary sites on the live system did not operate as expected, this was due to known limitation on the live network,*
  - *In some cases, there was a mismatch between the model and the live system of when Smart Street was active*
- **OC6 VR/DD & LFDD**: OC6 VR/DD and LFDD were successfully simulated to showcase the demand reduction methods and the corresponding effects of CLASS, Smart Street and NEM.
- **Tap Stagger**: Tap Stagger was simulated successfully and demonstrates the level of reactive power absorption that can be achieved by creating a tap differential at a pair of transformers.

Conclusions & Publications

Conclusions

- **Confirmation that the live SE QUEST system operates as per the functional specification** to perform QUEST control actions on the live network so that the benefits from QUEST can be realised. In some instances, differences between the two QUEST systems prompted questions regarding the response of the live QUEST system but these differences were generally because of known limitations on the live network.
- **Validation of the SGS QUEST system model**, which has been shown via the trial tests outlined in the report to perform closely in line with the live SE QUEST system.
- The simulated and live QUEST trials further support that **Conservation Voltage Reduction is an effective technique for leveraging the voltage/demand relationship.**
- Live trials limited to what could be tested in the real system. **Emergency functions**, i.e., LFDD, OC6 VR/DD, **could not be tested on the live system** due to significant impact on the network, but simulation was possible due to the Digital Twin.
- In future work, a more complex model could improve accuracy and precision of the resulting power and voltage outputs for the QUEST system model. However, this would only be required where accuracy and precision have a material impact to the proposed objectives.

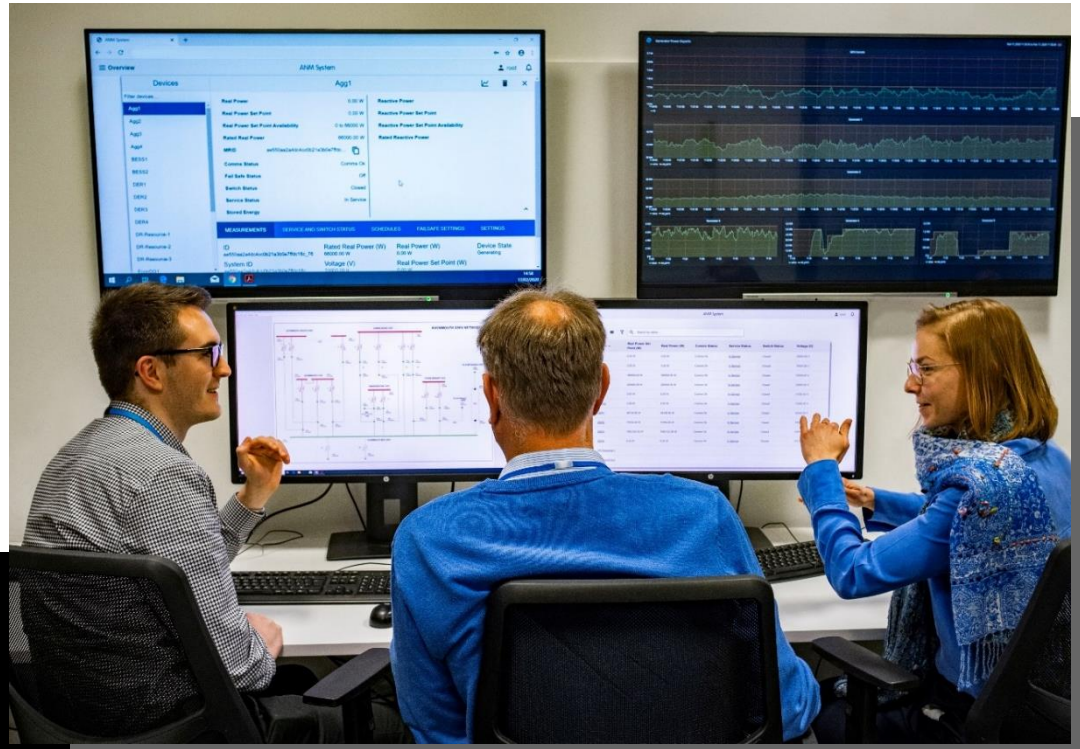
Publications:

- QUEST – An Overarching Control Solution (CIRED 2023)
- Voltage Demand Relationship Modelling For Future Energy Scenarios (CIRED 2023)
- QUEST – An Overarching System Control Solution: Operational Trials (CIRED 2025)
- QUEST – An Overarching System Control Solution: Live Trials & Digital Twin Validation (CIRED 2026 TBC)

Contact Us

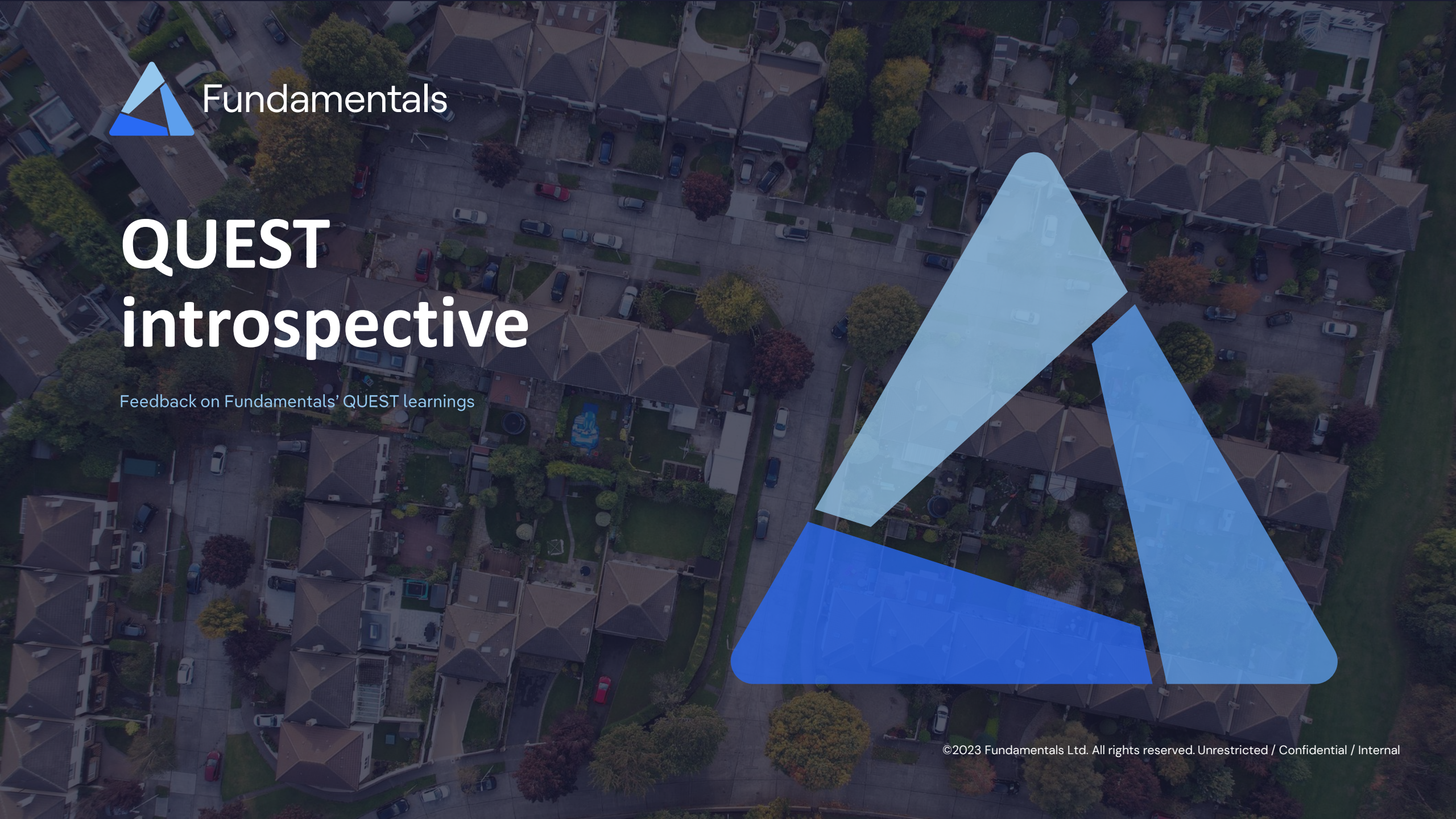
@Smarter Grid Solutions

@SmrtrGridSols



www.smartergridsolutions.com

Fundamantals



Fundamentals

QUEST introspective

Feedback on Fundamentals' QUEST learnings

Project review

Fundamentals will develop and implement an algorithm on their SuperTAPP SG relays to enable the QUEST functionality.

This algorithm will be incorporated into new relays which will be installed within the trial area at:

Bulk supply points

Primary substations

Upgrade the existing CLASS relays

Fundamentals

Key Fundamentals deliverables…to date

- Contribution to meetings, workshops and dissemination events
- Defining use cases and performing site surveys
- Installation and commission of nine SuperTAPP SG wall-boxes across Grid and Primary sites
- Verification and validation of the SuperTAPP SG software, firmware, and settings
- QUEST functionality enhancements within SuperTAPP SG relays
  i.e. Loss of comms detection - Extended voltage range - Feeder monitoring
- CLASS functional enhancements within SuperTAPP SG relays

Fundamentals

Total Voltage Control is.....

Tools	+	Function	=	Capability
Technology Products Services	+	Measurement Coordinated decision-making Actuation	=	Control of Voltage and Power throughout the grid

Fundamentals

Lunch – 40 minutes

Restart @ 12:50

Agenda

SP Electricity North West

Topic	Presenter	Time
Start & Welcome	SP ENW	10:00 - 10:10
Introduction	SP ENW	20 min 10:10 – 10:30
What we did with Our customers Money		10:30 – 14:30
SP ENW Overview	SP ENW	20min 10:30 – 10:50
10 Min Comfort Break		10:50 – 11:00
SGS “Provider/ANM” & “Research/Digital Twin”	SGS	50 min 111:00 – 11:50
Fundamantals Installations	Fundamantals	20min 11:50 – 12:10
Lunch		12:10 – 12: 50
SE Software Development. Use Cases to testing & debugging	SE	60min 12:50 – 13:50
Customer Engagement	Impact	20min 13:50 – 14:10
What we learnt		14:10 – 15:50
SP ENW Trials and Analysis	SP ENW	60min 14:10 – 15:10
10 Min Comfort Break		15:10 – 15:20
Project Partners	ALL	15:20 – 15:35
Formal Lessons	SP ENW	15:35 – 15:50
How are we going to use it	SP ENW	15:50 – 16:00
Closedown		16:00

Development of QUEST overarching Software

QUEST Design & Implementation

Project overview – **how collaborative approach brings success**

Agenda

1 Introduction

2 QUEST Design Overview

3 QUEST Development Overview

4 QUEST Trial Design Overview

5 QUEST Testing Overview

6 QUEST Lesson Learned Reports

7 QUEST Test & Trial Preparation Overview

8 QUEST Trials Overview

9 Challenges and Lessons

10 Next Steps – QUEST BaU Design

QUEST Design Overview

- YEAR 2021
  - First two phases of the project design successfully FINISHED
    - QUEST use cases definition phase - (June 2021)
    - QUEST detailed design phase (subphase 1 & subphase 2) (December 2021)

QUEST Design Overview

- QUEST use cases
  1. QUEST Network Efficiency
  2. Smart Street & Enhanced AVC incl. CLASS
  3. Smart Street & ANM
  4. Enhanced AVC incl. CLASS & ANM
  5. Smart Street, Enhanced AVC incl. CLASS & ANM
  6. Smart Street, Enhanced AVC incl. CLASS, ANM & LFDD
  7. Smart Street, Enhanced AVC incl. CLASS, ANM & OC6
  8. Smart Street, Enhanced AVC incl. CLASS, ANM & Reactive Power Response

QUEST Design Overview

- QUEST use cases definition phase
  - Goal: Focus on detection of the potential conflicts rather than conflict resolution
    - Define functional Use Cases for QUEST Voltage Control System
    - Understand all voltage control techniques and their impact on ENWL business processes
    - Consider combined operation to identify potential conflicts
    - Provide clarity on objectives, conflicts, and coordination needs
    - Lay foundation for QUEST architecture options

QUEST Design Overview

- QUEST use cases definition phase
  - What We Did to Satisfy Requirements?
    - **30+ hours of workshops** (virtual + away days) with ENWL QUEST team and partners
    - Collaboration across project partner teams:
      - Smarter Grid Solutions (Glasgow)
      - Fundamentals Ltd (Swindon)
      - ESO Network Development (Warwick)
      - Schneider Electric (Serbia)
    - Multiple draft revisions of Use Cases to cover scenarios, optimization opportunities, and possible solutions.

QUEST Design Overview

- QUEST Detailed Design phase (subphase 1 & subphase 2) (December 2021)
  - Goal: Develop and evaluate architecture options for the QUEST overarching control system
  - Subphase 1
    - Fill in the gaps within the first version of the Use Cases
    - Clarify and refine initial Use Cases for QUEST
    - Define preliminary options for conflict resolution (QUEST macro level architecture options)
    - Lay foundation for architecture options in Subphase 2

QUEST Design Overview

- Subphase 2
  - Goal: Explore architecture options for QUEST overarching software
    - Additional refinement of the Preferred Macro Option chosen within the previous subphase 1
  - Enhancements Introduced:
    - Updated coordination mode terminology: QUEST safe & mitigation modes
    - Meso-level options for flexibility (e.g., NEM safe modes)
    - Automated CLASS scheduling within QUEST and recommendations to explore additional CLASS modes (¼ and ¾ levels) in the next phase
    - OC6 mitigation split into two modes (OC6-VR-MM & OC6-DD-MM)
  - Validation: Architecture options meet previously defined QUEST objectives

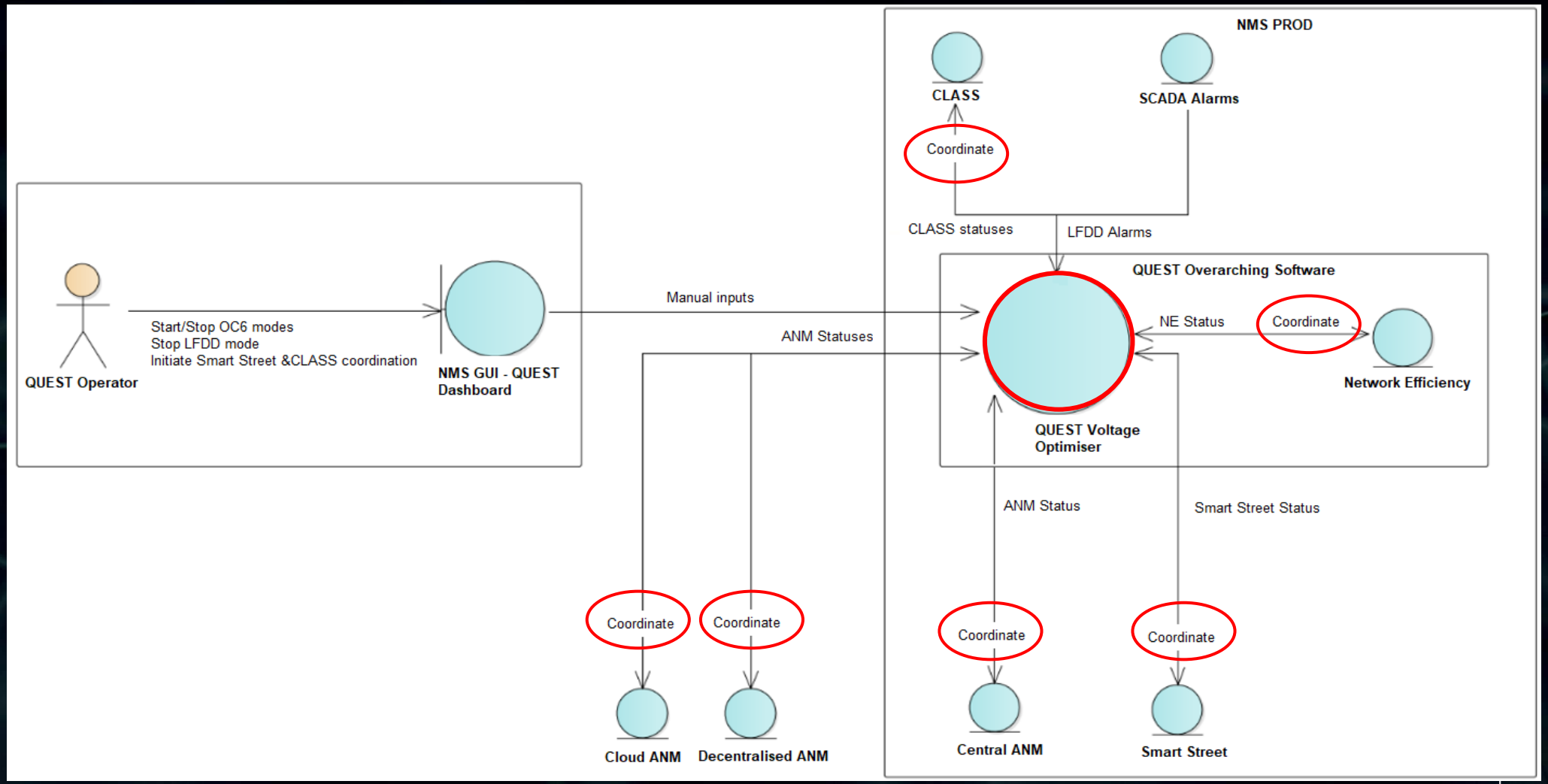
QUEST Design Overview

- YEAR 2022
  - Third design phase (Functional specification for the chosen architecture track) - FINISHED
    - Subphase 1 - January-March
    - Subphase 2 - March-June (QUEST Functional Specification)

QUEST Design Overview

- Subphase 1 – FINISHED in March 2022
  - CLASS Dashboard enhancements
    - Additional levels of voltage reduction (DRTQ & DROQ)
    - TSF on a BSP level – BSP TSF
  - New concept introduced:
    - SYSCON States - 6 system states for normal and emergency conditions
    - Technique Priority List (TPL) & BLENDs: Prioritization of voltage control techniques and configurable functional levels for CLASS, SMST, NEM
  - QUEST Contention Management Process (QUEST CMP) – QUEST offline simulations
  - QUEST GUI designed (Control & Monitoring, SYSCON Selector, Configuration, Dashboard)
  - QUEST architecture diagram changed in accordance with the additional requirements

QUEST Design Overview



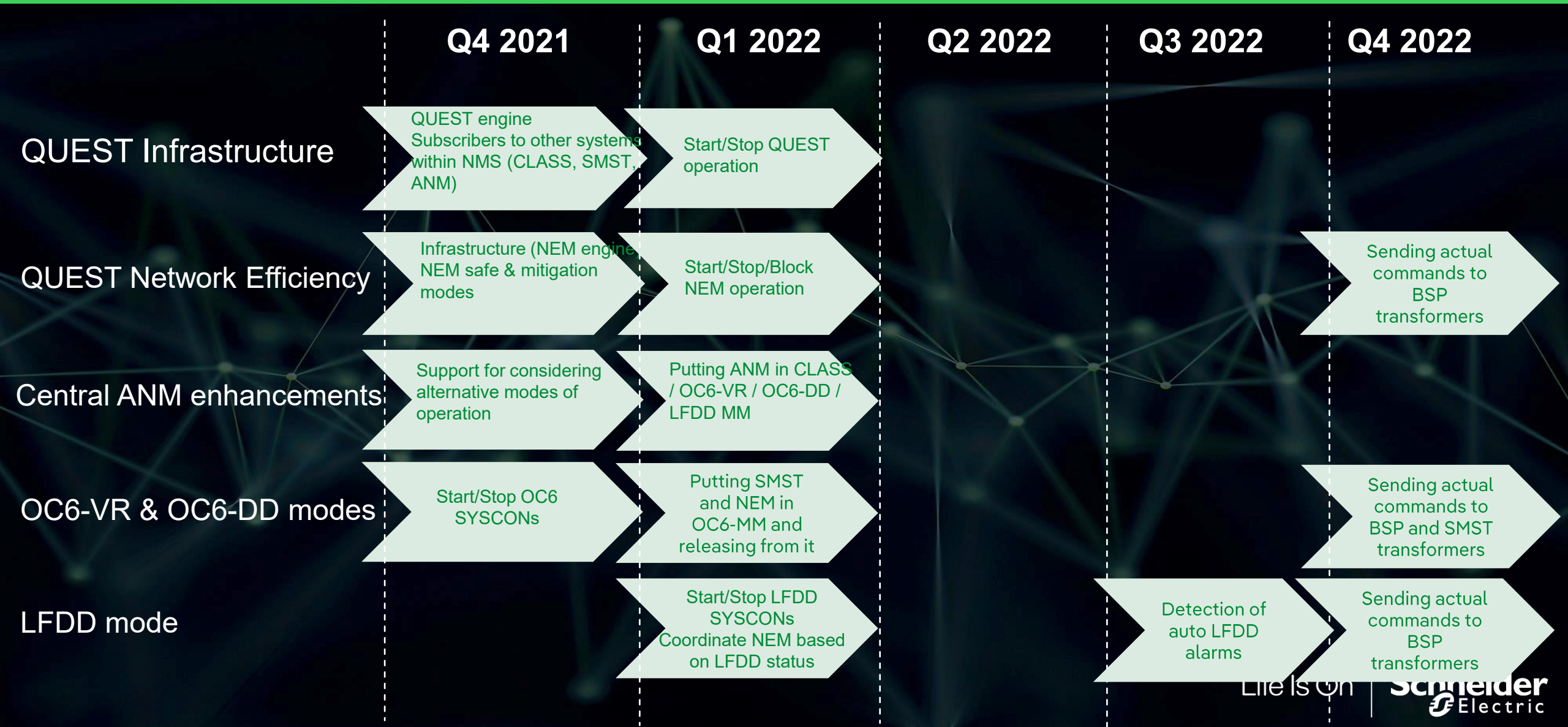
QUEST Design Overview

- Subphase 2 – FINISHED in June 2022
  - Functional specification for the chosen architecture submitted (QUEST Functional Specification)

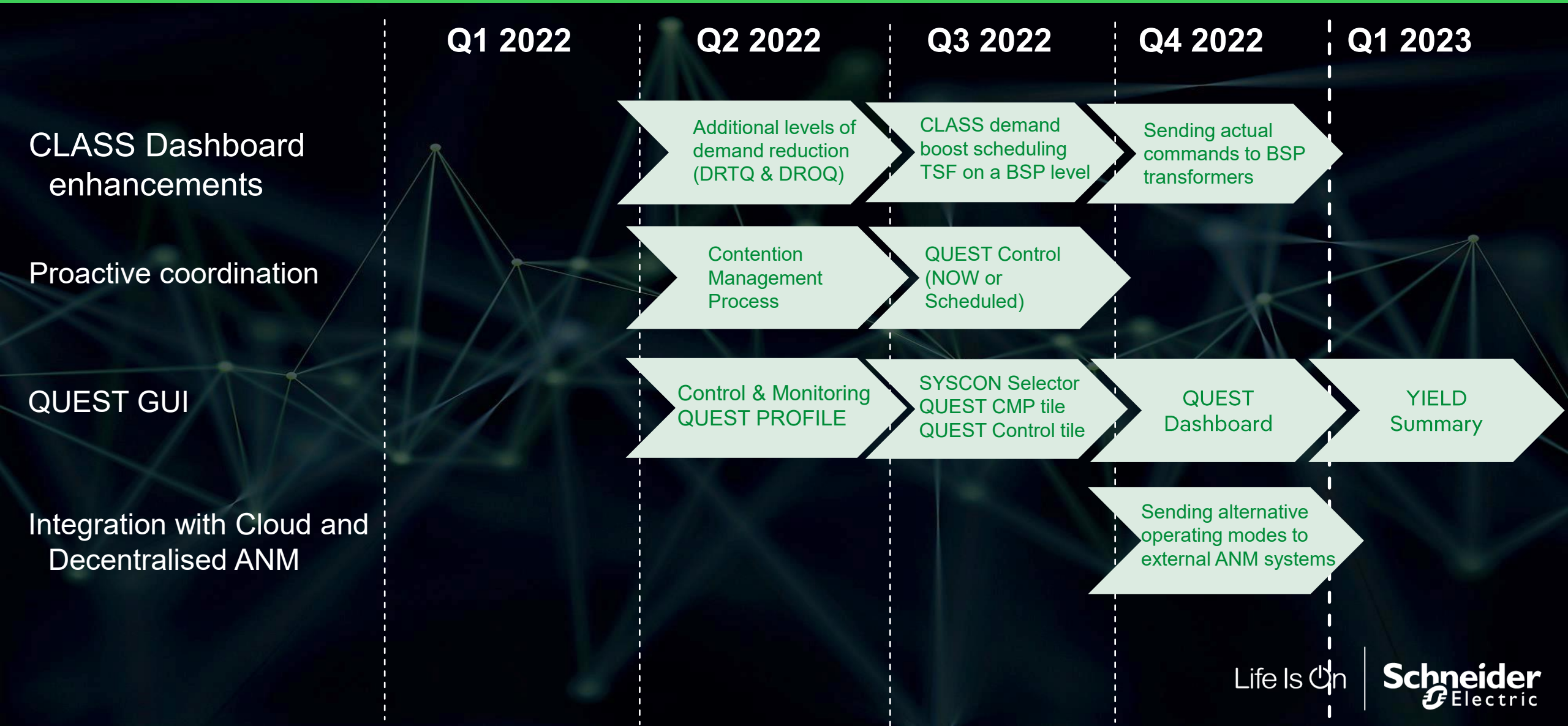
A special thanks goes to all the project partners who put in a lot of effort to contribute to the QUEST architecture definition – thank you for all your innovative thinking and brainstorming session without which this success would not be possible!

Together, as partners, we defined the basis for creation of an innovative, holistic solution that will have a major impact on network behavior and benefit customers.

QUEST Development Overview



QUEST Development Overview



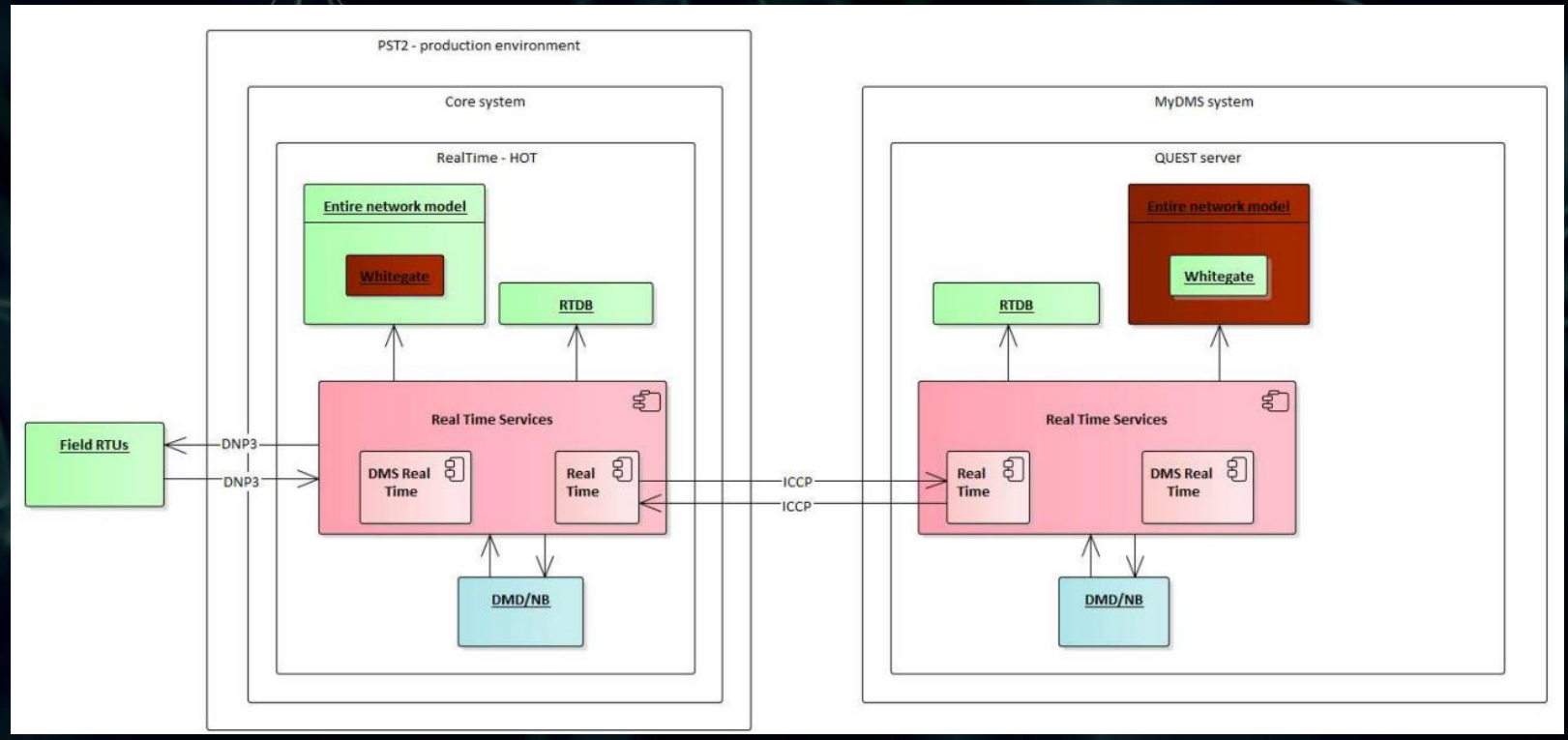
Life Is On | Schneider Electric

QUEST Trial Design Overview

- YEAR 2022
  - QUEST Trial Design report submitted - June 2022
  - QUEST Functional & Non-functional requirements defined – September 2022
  - QUEST test cases definition December 2022

QUEST Trial Design Overview

- QUEST production deployment configuration defined through the QUEST Trial Design report submitted



QUEST Testing Overview

- YEAR 2023
  - QUEST test cases written and mapped to QUEST functional requirements
  - QUEST Factory Acceptance Testing (FAT) & Site Acceptance Testing (SAT) successfully FINISHED (April & October 2023)

Life Is On | Schneider Electric

QUEST Testing Overview

Requirement definition

SE to define requirements and review with partners

Done in Q3/Q4 2022

Requirements **defined**, **confirmed** and **imported** to test link

Test preparation

Preparation of tests

Tests **defined** and **mapped** to requirements in Q4/Q1 2023

Test review

ENW to review the tests in an iterative process through Test Link

Done, end of February 2023

Tests **confirmed** end of February

Test Plan finalization

SE finalized administrative work and created test plan

Done, end of February 2023

Test plan and system **ready** for testing in April 2023

Test preparation

QUEST Testing Overview

FAT

Factory Acceptance Testing

April 2023

18-25th April 2023

FAT done on one QUEST machine with its network simulator environment

Successfully FINISHED with 91% pass rate

SAT

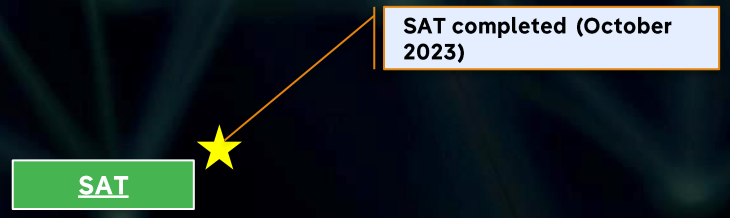
Site Acceptance Testing

October 2023

SAT – 02-06th October 2023

SAT done on one QUEST machine, deployed to UK, with its network simulator environment

Successfully FINISHED with 97% pass rate



Life Is On | Schneider Electric

QUEST Lesson Learned Reports

- Lesson Learned Reports
  - Last delivery from the project design succesfully FINISHED
    - Lessons Learned Report 1 - June 2023
    - Lessons Learned Report 2 - January 2024
      - Within these deliverables, updated QUEST Funtional Specification submitted
  - QUEST Trials and Analysis Report
    - Supported and reviewed by SE during November 2025
    - Summarizes QUEST benefits demonstrated during field testing

QUEST Test & Trial Preparation Overview

- QUEST Testing & Trial Preparation (November 2024 – May 2025)
  - QUEST Test and QUEST Prod environment setup
    - QUEST succesfully connected to ENWL test and production system via ICCP
    - ENWL peformed testing cycles to confirm the QUEST ICCP connection with test NMS system (PST1)
    - ENWL peforming testing cycles to confirm the QUEST ICCP connection with prod NMS system (PST2)
  - QUEST integration with SGS via ICCP

QUEST Trials Overview

- QUEST Trials (May 2024 – September 2025)
  - ENWL performed live trials until September 2025
    - SE provided support
      - (Bi)Weekly meetings organised to check the progress
      - Support provided in normal working hours 8-16h UK time
        - System check-up before each trial cycle
        - Assistance in the QUEST operation troubleshooting

Impact

Customer Awareness

IMPACT

FROM INSIGHT TO INFLUENCE

THE BIG 4 CUSTOMER RESEARCH QUESTIONS WE ANSWERED

1

The Customer Experience

- Did customers notice when voltage control was applied? If so, how was it perceived in terms of acceptability?
- Are the operating characteristics of generators and sensitive customers affected by voltage control, and under what conditions?

2

Customer Requirements

- Are there any specific voltage supply requirements for certain customer types?
- What impacts did voltage profiling have on generator customers?

3

Implementation and Engagement

- How do customers engage with the need for and implementation of QUEST?
- What communication and engagement strategies will be most effective in ensuring customers are well-informed and supportive of the transition to QUEST's optimised voltage management system?

4

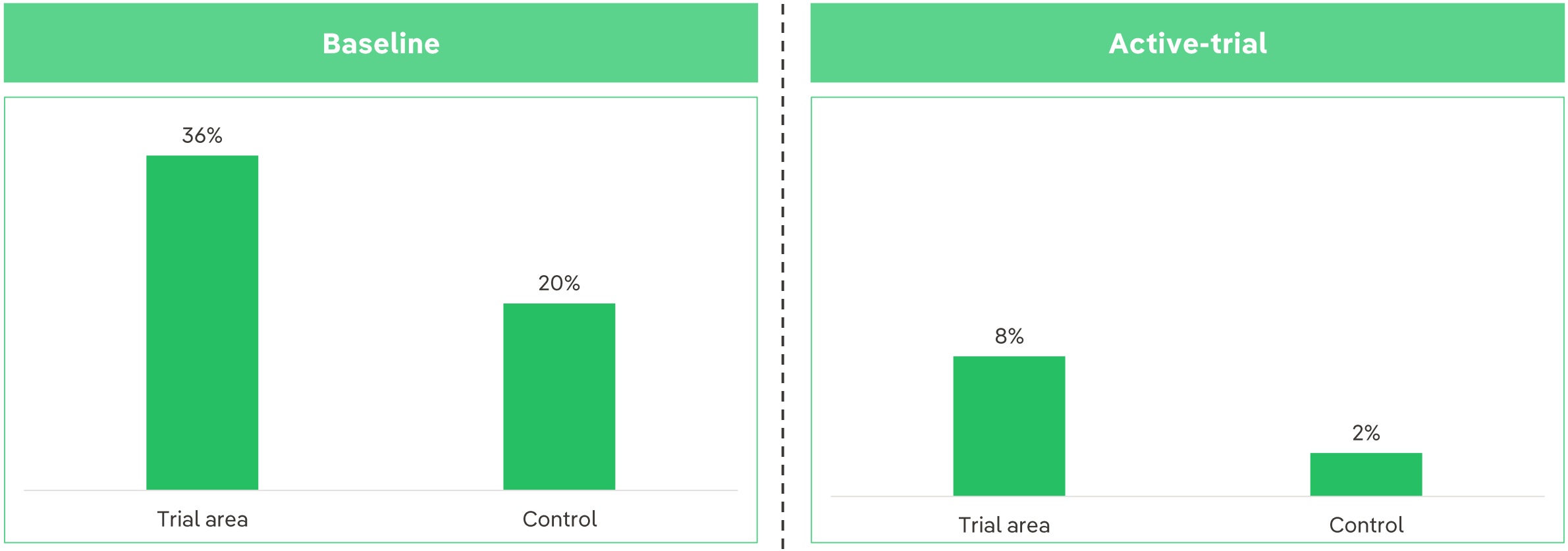
Appetite for Managed Connections

- What was the interest among customers, esp. generators and developers, for bespoke, managed connections?
- What are the technical and operational constraints related to voltage-managed connections, and what benefits did customers perceive?

AREA 1: CUSTOMER TRIAL IMPACT

HAVE YOU NOTICED ANY CHANGES IN APPLIANCE FUNCTIONALITY?

Reported changes in appliance functionality have decreased since the 2023 baseline. Although active-trial respondents had slightly higher rates of reporting changes than active-trial control respondents, this is not statistically significant and suggests that the trials have not had a noticeable impact on appliance functionality.



N3: Thinking about the **last few months**, have you noticed any of your appliances/electrical items ***acting different e.g., working slower than usual*** at certain times of day? Please do not include changes to internet speed here. Base size, baseline trial: 201, baseline control: 105
N3: **Since the start of June 2025**, have you noticed any of your appliances/electrical items ***acting different e.g., working slower than usual*** at certain times of day? Please do not include changes to internet speed here. Base size: Trial: 180, Control: 83

ASSESSMENT OF THE IMPACT OF QUEST TRIALS

No noticeable changes for most customers

Domestic and SME customers did not report any significant differences in electricity supply, appliance performance, or lighting since the QUEST trials began. **The project hypothesis that "customers will not discern any changes in their electricity supply when operating across the permissible voltage range" was positively revalidated.**

1

Comparability between trial and control groups.

For the vast majority of measures, we see similar attitudes and reported behaviours among both the trial and control samples.

2

High baseline satisfaction

Satisfaction with SP Electricity North West's service was high in the baseline, and no evidence of a trial-related increase in contact with the DNO.

3

Specialist equipment unaffected

Among SMEs with specialist electrical equipment, none reported any positive or negative impacts on performance during the trial period.

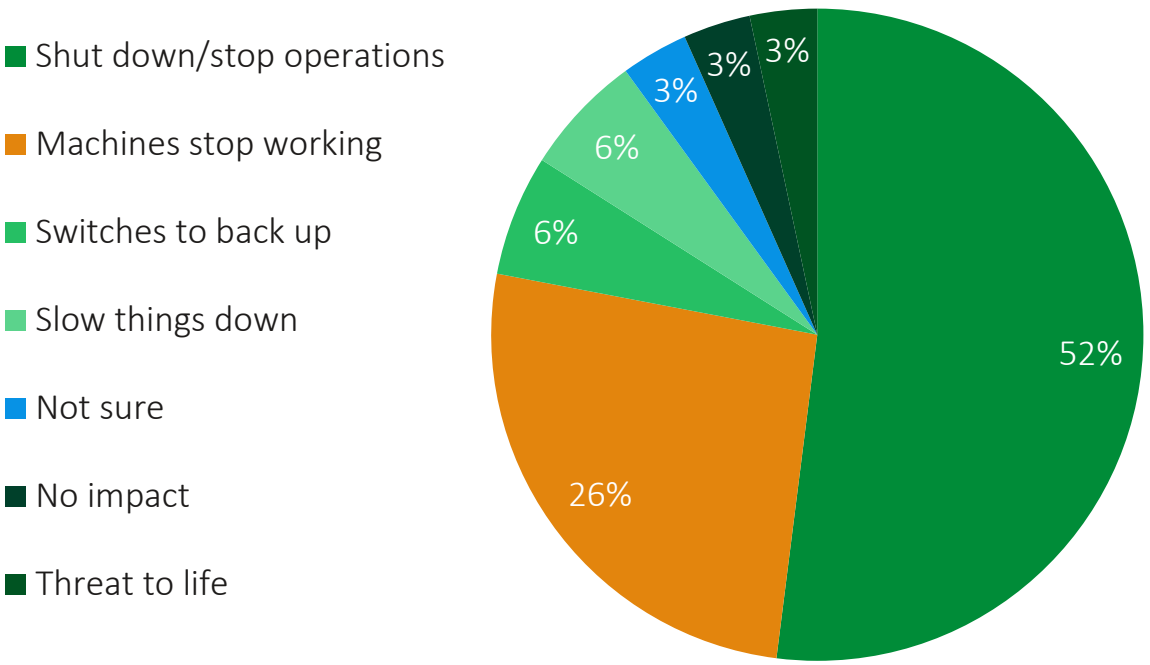
4

AREA 2: QUEST ENGAGEMENT

IMPACT OF VOLTAGE CHANGES

Businesses raised a number of operational, financial, safety and reputational risks. Over half of organisations thought their operations would shut down if the voltage fell outside the desired range.

Impact on organisation if voltage fell outside of prescribed narrow range:



Operational disruptions

Supply chain and client relationship impact

Financial impacts

Sector-specific challenges

Equipment damage and maintenance

Communication and mitigation needs

Safety and compliance risks

WHAT DO BUSINESSES THINK ABOUT THE FUTURE?

- In general, businesses showed little understanding or awareness of how pressures on the electricity supply has changed or will change in the future.
- Whilst they had experienced issues from voltage fluctuations, there was little spontaneous mention of this strain on the network increasing as time goes on. When prompted, businesses did appreciate the need for greater voltage control, but currently did not have long term plans or strategies for internal management of likely supply problems

Once QUEST was explained to the groups, the future strain on the network did play a role in the perceived benefits of QUEST:

"If it's something that's predicted is going to continue, and is going to get worse, no doubt with the demise of natural gas in the not-so-distant future, and if we're going to rely on renewables as opposed to nuclear. Yeah, absolutely."

- **Plant Manager at a Power Station**

However, not everyone took this statement as the absolute truth:

"It's like they're a fortune teller. That might happen in the future, but what if it doesn't?"

"I'd rather they say, 'last year this many things happened to your supply, and this is the effect. It had to mitigate that risk. We can do this.' I'd rather it be that than someone try and say, oh this could happen in the future so you should be safe and act now"

- Operations Manager at a Hospital

INFO SHOWN TO CUSTOMERS

QUEST will allow for multiple, concurrent voltage management techniques to be running across the network

This will unlock capacity for customers and help facilitate the adoption of low carbon technologies

QUEST EVALUATION: PERCEIVED BENEFITS

The most compelling benefits were efficiency improvements and related cost savings. Environmental benefits secondary. Less fluctuation, and therefore fewer outages, was seen as a real positive.
It was made clear to respondents that ENWL would remain within statutory limits when adjusting voltage. This was not raised as a concern by businesses

Environmental benefits

- Reducing Co2
- Support for renewable energy and low carbon technologies

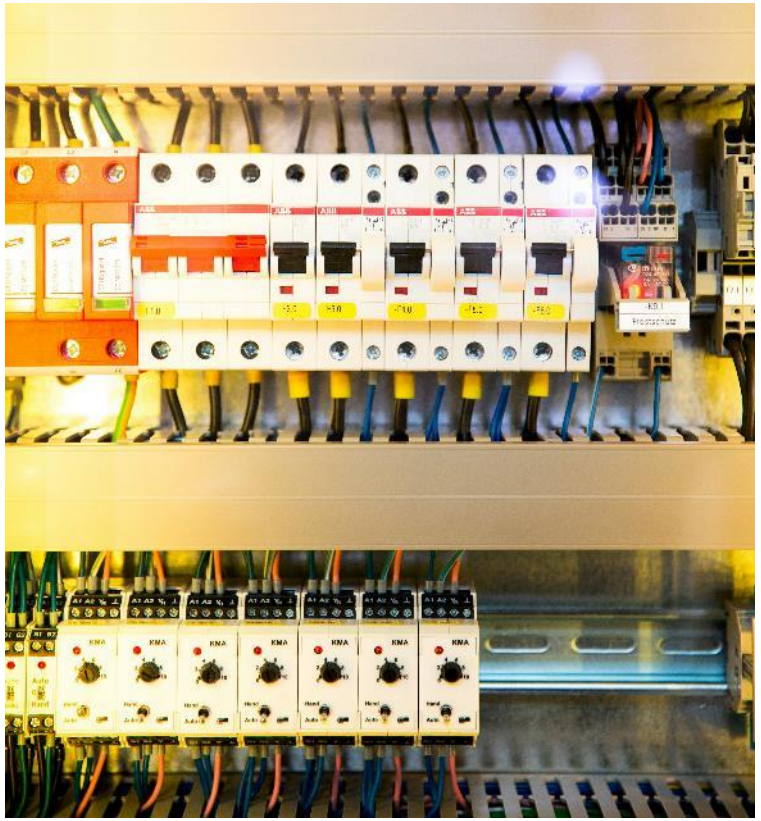
Technical assistance and advanced monitoring

Improved safety

- Reduction of electrical fire risk

Stabilising the grid:

- Increased reliability
- Money saving as there will be fewer outages
- Can maintain continuous operations



"So a lot of these audits, if we can understand better supply, obviously that will then benefit us and feed into those figures that we can measure. And so for me it's that community of different things sort of feeding into us."
Operations Director at a Corrugation Manufacturer

"If you can put those statistics and facts on a bit of paper and prove that it works, then NHS are on board."
Network Manager for NHS Trust

QUEST is an innovation project by Electricity North West (ENWL) designed to optimise voltage levels across the electricity network. QUEST is trialling new voltage control techniques that will improve the reliability and efficiency of energy delivery, particularly benefiting businesses that rely heavily on high voltage energy.

Current voltage management techniques are specific to individual voltages and less effective as a result. QUEST will trial the co-ordinated control of multiple voltage management techniques (whilst remaining within statutory limits) to meet the changing demands being placed on the network.

Why is QUEST Needed?

As the UK progresses towards decarbonisation and a greener future, the demand for electricity is rapidly increasing and becoming less predictable. More electric vehicles, heat pumps, and renewable energy sources are being integrated into our daily lives and the electricity network. This increasing ebb and flow in demand can lead to voltage fluctuations, which pose several challenges for businesses:

- **Increased Demand:** The growing use of electric technologies puts additional strain on the existing electricity infrastructure, necessitating more efficient and resilient management of voltage levels.

- **Increase in Renewable Energy Generation:** Achieving the UK's decarbonisation targets requires the integration of more renewable energy sources, which can introduce variability in power supply. Effective voltage management ensures a stable and reliable grid despite these changes.

Addressing Your Concerns:
We understand that voltage fluctuations can affect your equipment which could lead to significantly impacts on your business including:

- **Operational Disruptions:** Unplanned shutdowns and downtime affecting productivity.
- **Financial Impacts:** Costs associated with equipment damage, maintenance, and operational delays.
- **Safety and Compliance Risks:** Potential hazards and regulatory challenges due to equipment malfunctions.
- **Supply Chain and Client Relationship Impacts:** Delays and defects affecting timely project completion and client trust.

How QUEST Helps:

- **Improved Control:** By giving overarching control across all network voltages, QUEST can respond to the changing demands placed on the network by the move to net zero. Leading to:
  - Easier identification of and faster response to developing issues on the network
  - Ability to utilise the network more effectively by optimising voltages at all levels simultaneously
- **Reduces Carbon Footprint:** Significant reduction in emissions by 2050.
- **Financial Savings:** Optimising voltages means less new network infrastructure is needed to manage demand. As ENWL income comes from customer bills, this minimises electricity bill increases. Cost savings are also made by reducing energy losses across the network.
- **Increases Network Capacity:** Frees up capacity to facilitate lower-cost connection of low-carbon technologies (LCTs).
- **Growth Opportunities for Generators:** Option to enter into voltage-related contracts with ENWL to increase power exports to the grid at times when there is more available capacity

Considerations for businesses using higher voltage electricity:
The increase in demand and generation caused by the growth in low carbon technologies will increase the range of voltages experienced by businesses. QUEST voltage control techniques will minimise this although some business may need to consider:

- **Equipment Sensitivity:** Some highly sensitive equipment might require recalibration or adjustment to function optimally under the changed voltage management conditions.
- **Backup Systems:** Businesses should ensure that their backup systems are compatible with the changed voltage management conditions to avoid any conflicts or inefficiencies during the transition.

Support available to businesses from ENWL:

- Customers should report any problems to ENWL's Customer Centre, detailing the type and nature of the issue.
- Technical Investigation: ENWL will allocate technical resources to investigate, using high-accuracy monitoring equipment.
- ENWL will communicate and resolve any issues identified
    - If the supply meets the regulations, we will inform the customer and close the concern.
    - If the issue is with the customer's own equipment, ENWL's advice and ability to help will be limited, and the customer will need to take action themselves

For more information about QUEST and how ENWL will work with your business, please visit our website or contact our dedicated support team. We are here to help you navigate these changes and ensure a seamless transition to improved voltage management.

In the future, ENWL may be able to offer customers access to **enhanced support.** If customers want these services, they may be offered by partners and businesses can choose to pay for them:

- Advanced voltage monitoring with real-time alerts
- Technical assistance to assess equipment vulnerability
- Financial support for proactive mitigation measures
- Power quality improvement solutions (e.g. voltage regulators)

CHANNEL PREFERENCE

Both emails and in-person events were commonly suggested, but people stressed the importance of the information coming from a named contact. Generic emails were likely to be ignored.

Tailored Email:

- Quick and direct
- Preferably from a named contact

Real-time updates:

- Real-time monitoring of electricity prices
- Would help generator decision makers decide whether they want to get more out of the plant

In-person events:

- Biggest impact but low attendance risk
- Can engage with the information to a greater degree

AREA 3: MANAGED CONNECTIONS

Developers reported several ways in which changes to the sector are impacting their decision-making when it comes to connecting new sites to the grid,

Challenges in securing capacity

- Grid capacity is increasingly constrained.
- Developers face more difficulty in securing new connections

Increase in phased developments

- Developers are increasingly looking at phased projects, where they might power a wind farm or solar site in stages.
- This allows them to work with the existing grid connection and upgrade it progressively as more capacity becomes available.

Impact on site selection

- Developers are placing more importance on whether a site can secure a grid connection in the first place.
- Previously, developers might have focused more on land availability and other factors, but now grid access is a major (and sometimes primary) consideration in site selection.

Financial optimisation

- Utilisation of hybrid (solar, wind, and battery) to solve the highs and lows typically associated with wind farms.
- Batteries being used to maximise revenue through storage.

INTEREST IN BESPOKE CONNECTION AGREEMENTS

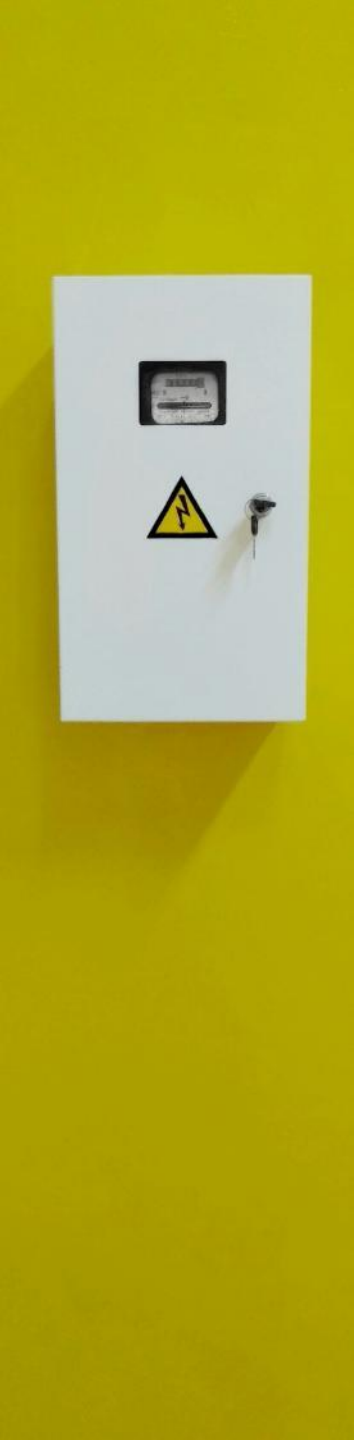
Customers saw the main benefits as being able to get connections they otherwise wouldn't get capacity for and potentially increasing export revenue by exporting more when the grid needs it

- **Key opportunities:**
  - **Renewable generation developers and operators (owners) and M&A investors**
    - Benefit if they could repower / install a higher capacity than their connection agreement, and use the extra capacity in a way that won't harm the network
  - **Batteries (BESS) as they can naturally be more flexible – can help to smooth the export curve when linked to solar generation**
    - This could be a real benefit if battery operators could have extra capacity and get the upside of that
  - **Engaging with large land owners and investment companies that have overall control of financial targets**
  - **Could be a marketing win as businesses can position themselves as working in partnership with the grid**

- Lower interest groups:
  - **<u>Not</u> solar generators as is only financially viable if they can maximise sunlight hours**
  - **<u>Not</u> housing developers as they sell the sites on**
  - **<u>Not</u> businesses that don't have overall control of their site (e.g. power station is owned by an investment company, ship manufacturer's site is owned by the council)**

"Sometimes we can't get the capacity or the point of connection we want due to voltage issues, but that is with the assessment being that the site is exporting or importing continuously at full capacity or using quite conservative assumptions. So what you're describing means you might get offered a point of connection that otherwise might not have been possible as long as these conditions are as part of the offer."
- Generation developer

"[Having capacity constrained] is going to discourage private investors from putting up solar or wind turbines because it's going to increase the length of time that they have to run it before they can see their money coming back"
- Farmer with large turbine



ABILITY TO RESPOND TO VOLTAGE SIGNALS

- Customers needed more information on what voltage signals would be given by the DNO and how / when they would be given

- Power stations were able to change their voltage / power factor etc but this has impacts on other areas of operations
    - **e.g. boiler pressure, cost of importing power to keep the system hot, pressure from investors to maximise export**

- Some businesses were open to responding but didn't know whether their equipment would be able to respond to the signals
    - **Can change voltage through the transformer but it isn't something they do regularly**
    - **It's necessary to speak to multiple people within a business to get a full picture of ability**

- Opportunity for DC inverter behaviour change
    - **Solar and battery developers / generators would be a natural fit with bespoke connection agreements as they have an interest in both import and export flexibility.**
    - **As solar equipment is DC, customers could potentially use their inverters to control the amount of power converted to AC and exported to the grid.**
    - **The customers interviewed for this research did not know whether their technology was able to do this but agreed it could be an option for responding to voltage signals**

- Generator customers did not engage with the potential benefit of being able to access other energy markets. They would need more details of how this would work to be able to discuss this in detail

"It's easier to run lower, it's easier to turn off. It's not a difficult thing to do. Obviously it's all about the money, isn't it. But as a site and as operators, it wouldn't be a problem and I think it would be beneficial."
- Biomass power station

"It would have to be a consultation at quite a lot of levels - financially, of course, but also in terms of the production managers, and it might not impact them directly, but it is a policy that they would have to remind subcontractors and people further down the train."
- Ferry manufacturer

QUEST CUSTOMER RESEARCH: CONCLUSIONS

1. **QUEST met its objectives:** improved network efficiency with no disruption to day-to-day experience.
2. Domestic and SME customers reported **no change in supply quality,** appliance performance, or satisfaction.
3. Customers generally **accept voltage control when explained**, and are comfortable with it operating in the background.
4. **Engagement with and awareness of the need for QUEST is low,** especially among I&C customers; Area 2 showed limited understanding even with voltage-sensitive equipment.
5. Sensitive and high-demand users rely on stable voltage, but **recruiting suitably knowledgeable businesses was challenging;** Area 3 had fewer able to discuss bespoke managed connections.
6. **Interest in bespoke, voltage-managed agreements is narrow** and depends on a clear financial case, operational feasibility, and regulatory clarity.
7. **Next steps:** targeted education and outreach for industrial and generation sectors to build understanding of network pressures and where QUEST can add value.

Thank you – Any questions?

Alice Broomhall
alice.broomhall@impactmr.com

Darryl Swift
darryl.swift@impactmr.com

Office: **44 (0) 1932 226793**

Impact Research Ltd, 3 The Quintet, Churchfield Road, Walton-on-Thames, KT12 2TZ, United Kingdom

All projects are carried out in compliance with the ISO 20252 international standard for market, opinion and social research and GDPR.

IMPACT

FROM INSIGHT TO INFLUENCE

The Project

SP Electricity North West

Refresh – Why and What did we set out to do

Inform – The What and How of what we did and

- Why we are confident to have made the previous statement
- Supported by our project Partners

Learn - What lessons can we take, to make future innovation better

Use - What are SP ENW plans to use QUEST in future (and issues therein)

OVERARCHING CONTROL SYSTEM
QUEST

The Trials

Introduction

Purpose of QUEST

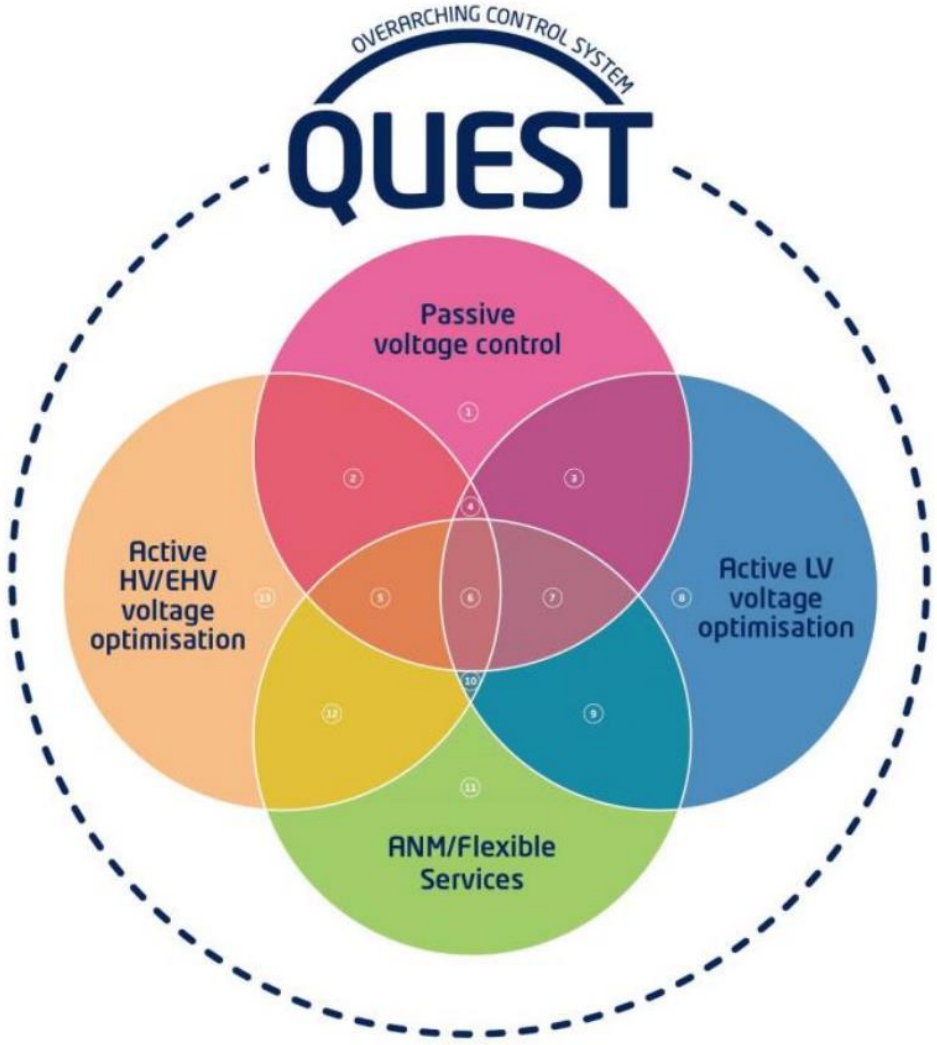
- Whole-system voltage optimisation across all network levels
- Integration of multiple techniques CLASS, Smart Street, NEM, ANM, Tap Stagger

Industry Need

- Rising demand from Low Carbon Technologies (LCTs)
- Existing discrete solutions (CLASS, Smart Street) lack coordination
- QUEST addresses these limitations by providing holistic optimisation

Objectives of the trials

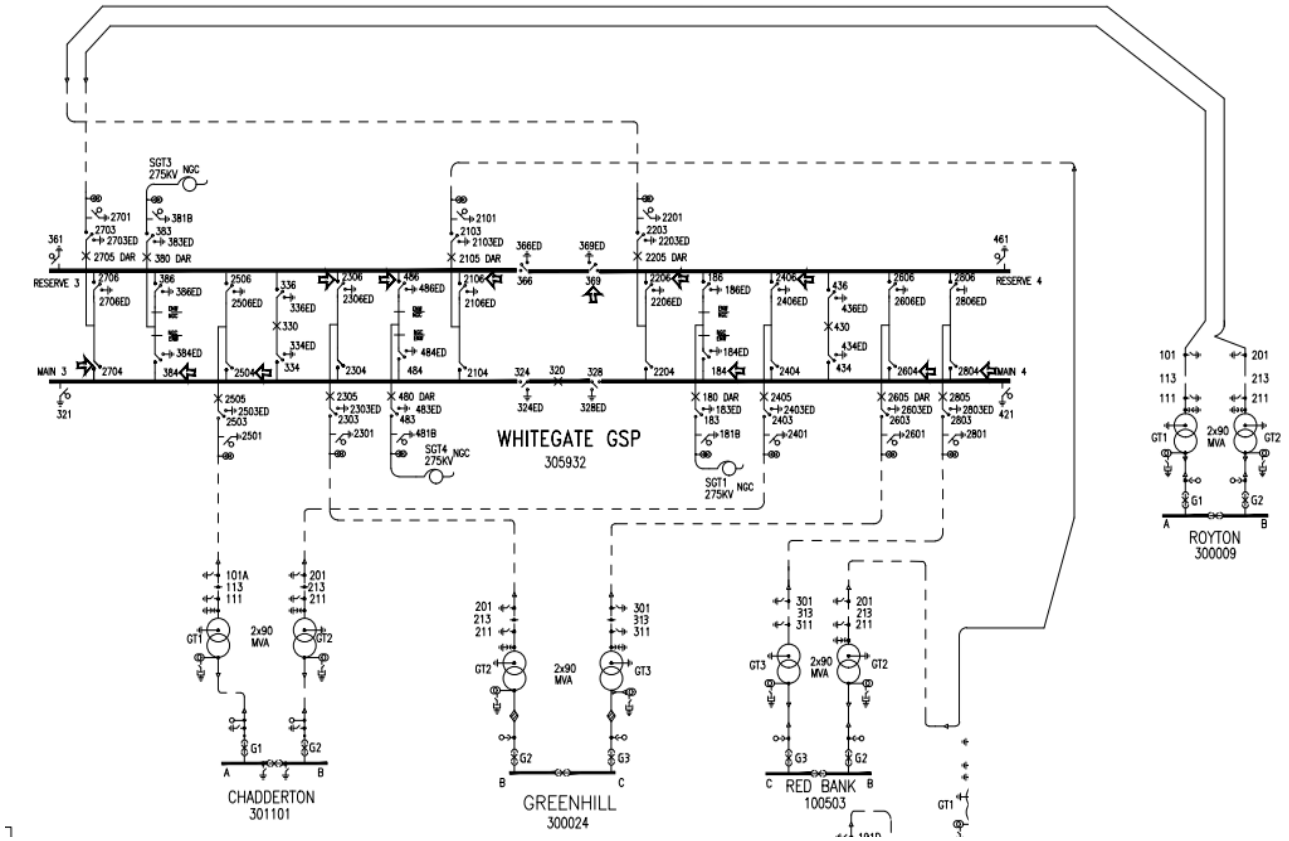
- Validate that QUEST can coordinate multiple voltage control techniques—CLASS Demand Reduction and Boost, Smart Street, Network Efficiency Mode, Tap Stagger, and ANM.
- Test across a wide range of scenarios: single-technique activations, multi-technique coordination, emergency transitions like OC6 and LFDD, and reactive power support.
- Measure performance against key criteria: demand reduction and boost targets, voltage compliance, loss reduction, and emergency response readiness.
- And finally, assess readiness for Business-as-Usual deployment—what works, what needs refinement, and what lessons we can take forward



Trial Area Overview

Scope of the Trials

- Trials conducted across the Whitegate GSP area (4 BSP's, 26 Primary Substations)
- Test and Production environments
- Included over 100 test scenarios, ranging from single-technique activations to complex multi-technique coordination
- Covered all states: Normal, OC6 VR/DD, LFDD and transitions between them.



Whitegate GSP Area

Techniques Involved

11kV / 6.6kV

CLASS

CLASS Demand Reduction

Reduces network demand by lowering voltage at primary substations

- Demand reduction full – targets 5% nominal voltage reduction
- Demand reduction three quarters – targets 4%
- Demand reduction half – targets 3% nominal voltage reduction
- Demand reduction one quarter – targets 2% nominal voltage reduction

Class Demand Boost

Increases network demand by raising voltage at primary substations

- Demand boost full – targets 5% nominal voltage increase
- Demand boost half – targets 3% nominal voltage increase

0.4kV

SMART STREET

Smart Street

Applies Conservation Voltage Reduction (CVR) at secondary substations by adjusting transformer taps to lower LV voltages. This technique reduces energy consumption and customer demand without impacting service quality

Under normal operation, optimal tap positions for services transformers keep LV voltages as close a possible to statutory limits

Techniques Involved

132kV / 33kV

OVERARCHING CONTROL SYSTEM
QUEST

Network Efficiency Mode (NEM)

New technique designed to improve network efficiency by reducing system losses on the 33kV network. This is achieved by raising voltage targets at BSP transformers which lowers current flow and associated losses.

132kV / 33kV

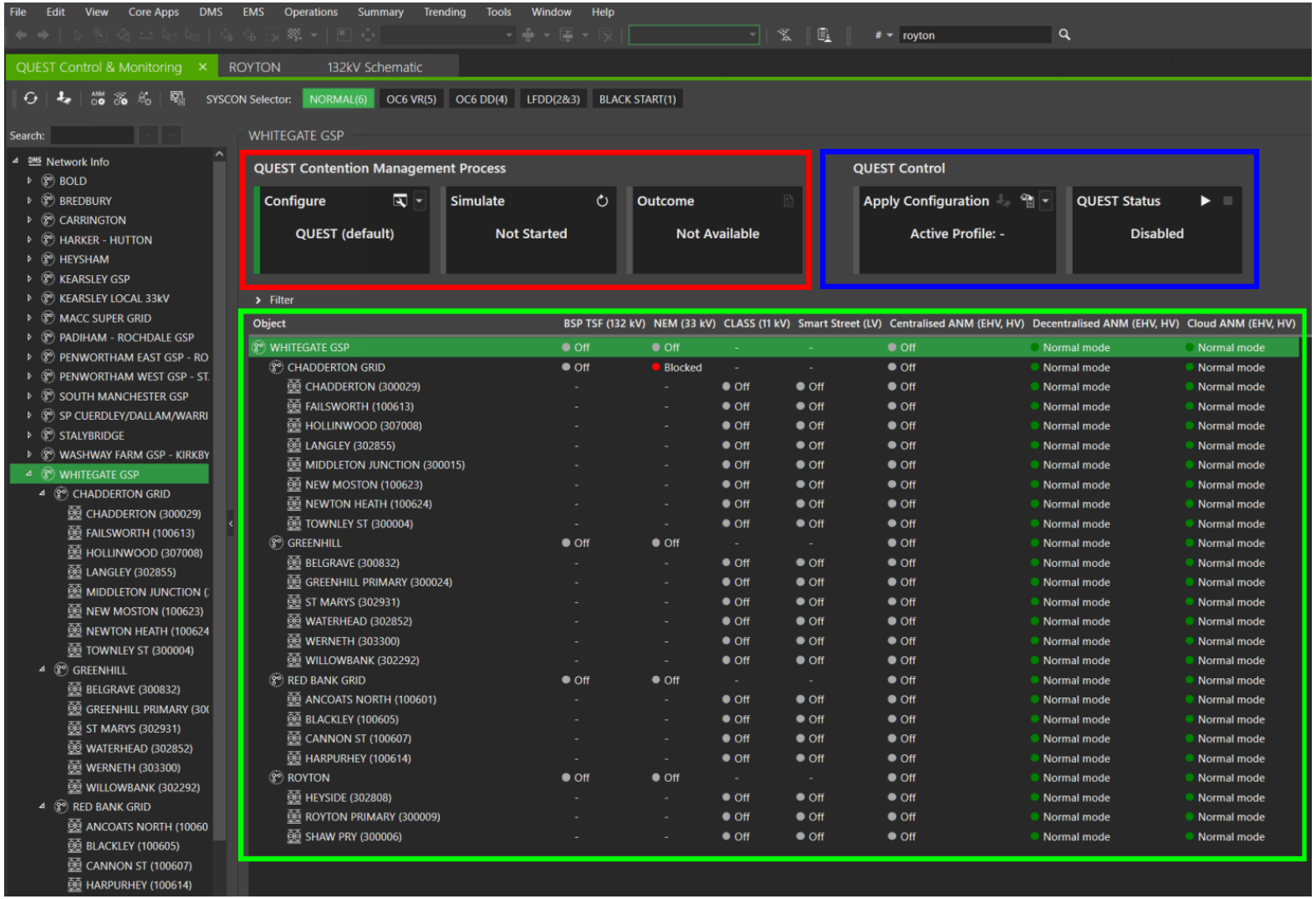
OVERARCHING CONTROL SYSTEM
QUEST

BSP Tap Stagger

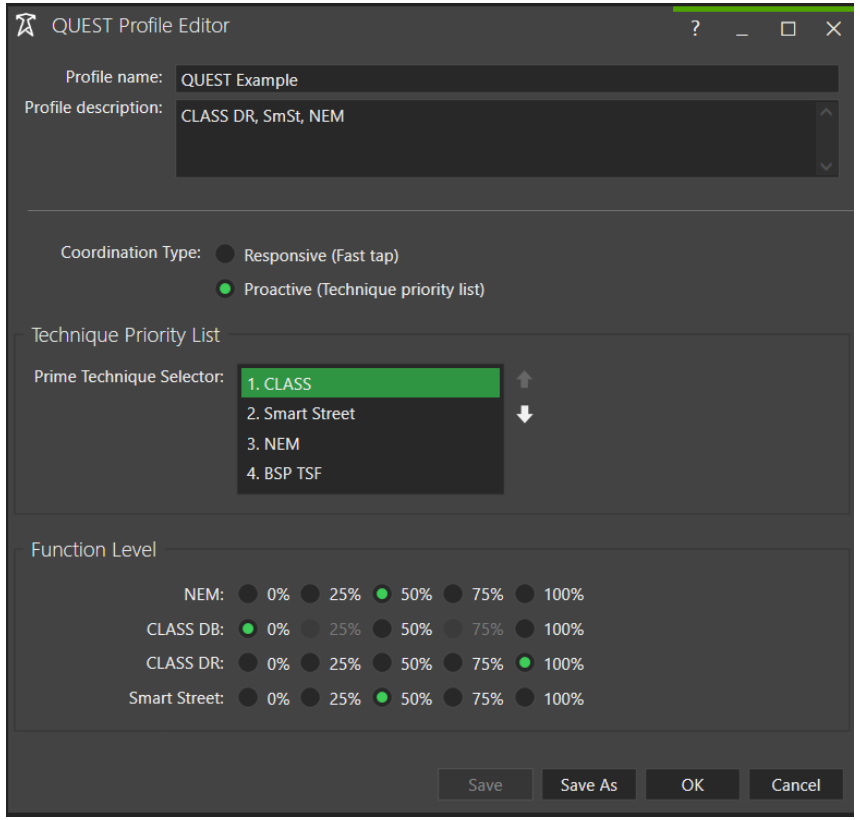
New technique which creates a controlled reactive power sink by introducing a tap imbalance between paired BSP transformers. Three stages of TSF were introduced, TS1 which is 2 taps apart, TS2 4 taps apart and TS3 6 taps apart from one another.

QUEST System Overview

- User interface, expanded network tree with QUEST functionality

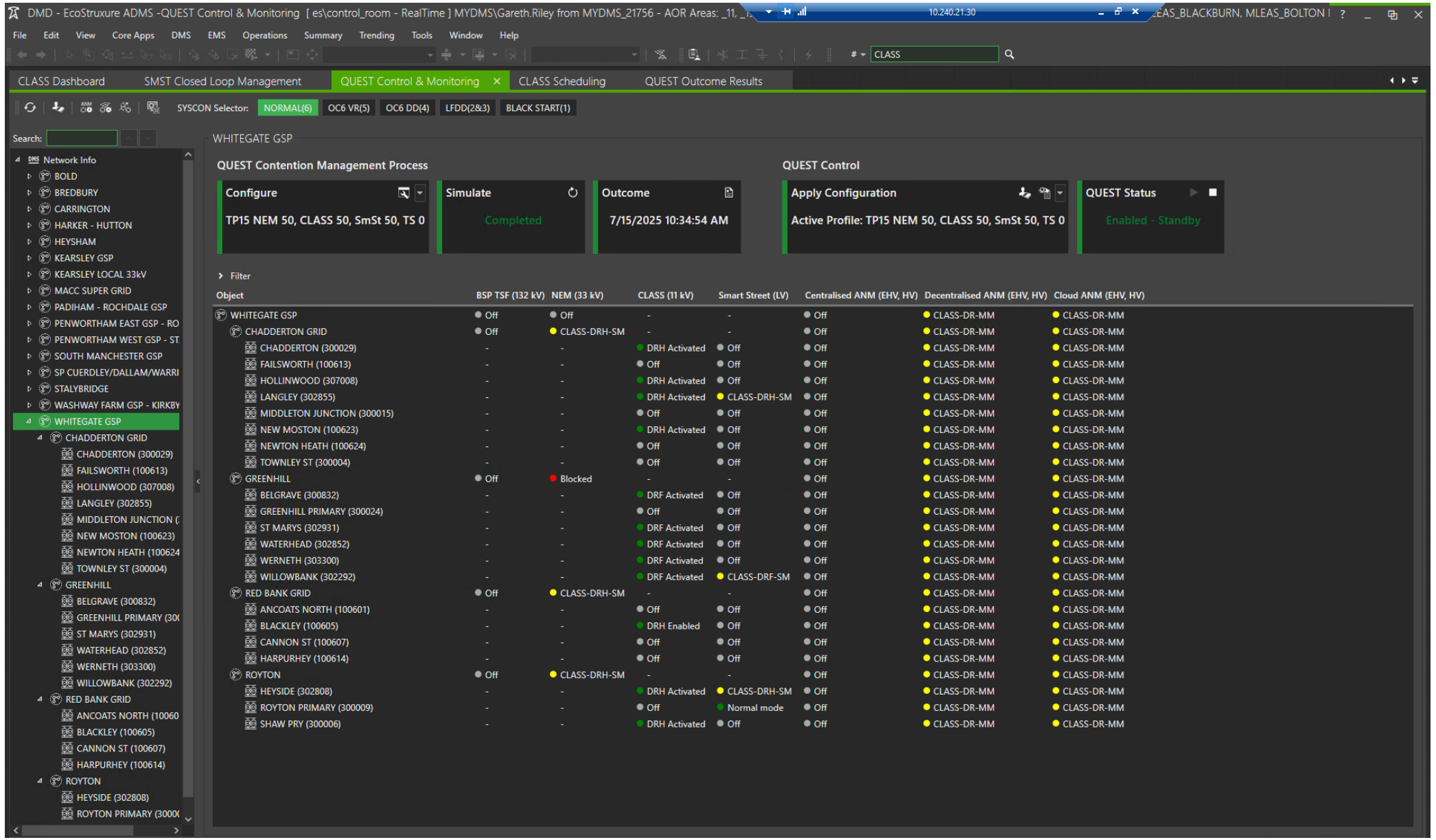


Control & Monitoring Dashboard

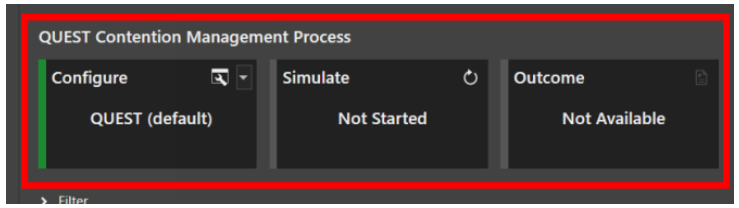


Profile Editor
(Primary Inputs)

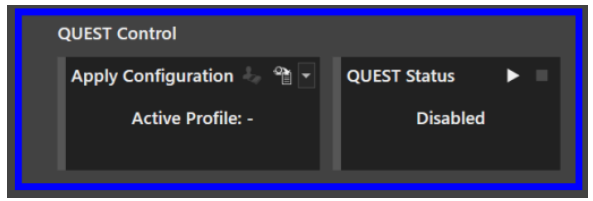
QUEST Dashboard - Activated



Simulation dashboard – validation before activation



Live dashboard – providing yield summaries



SP Electricity North West

QUEST Dashboard

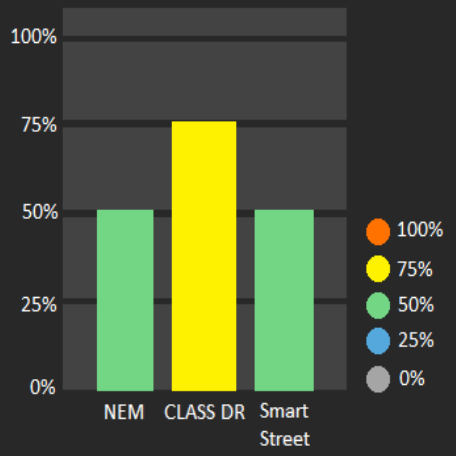
Updated time: 3/8/2022 11:22:03 AM

QUEST Input

Technique priority list

1. CLASS
2. Smart Street
3. NEM
4. BSP Tap Stagger

Function level



Yield summary

CO_2 reduction

CO_2 63 kg/s

Previous half-hour [kt CO2e]	0.2	0.5
This day [kt CO2e]	6.2	25
This week [kt CO2e]	40	175

Customer savings

£ 250 £/s

Previous half-hour [k£]	76	150
This day [k£]	37.5	150
This week [k£]	125	1000

Energy reduction

2.5 MWh (projected)

Previous half-hour [MWh]	3.2	6
This day [MWh]	112.5	450
This week [MWh]	375	3000

Demand reduction

MW 2.5 MW

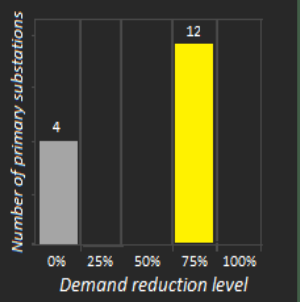
Previous half-hour [MW]	1.6 1.8	3
This day [MW]	1.9 2.3	3
This week [MW]	2.4 2.8	3

QUEST Output

CLASS DR — Function level 75%: 12 achieved

1 MW

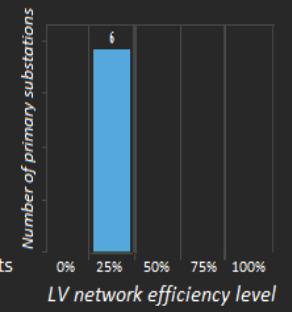
CLASS DR Target



Smart Street — Function level 50%: 0 achieved

1200

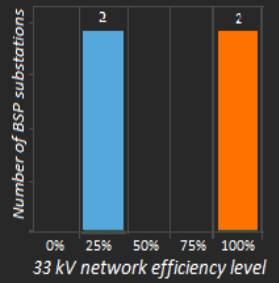
Number of customers getting Smart Street benefits



NEM — Function level 50%: 0 achieved

466 kW

33 kV losses reduction

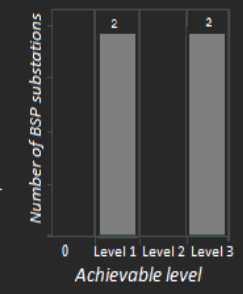


BSP Tap Stagger

Inactive: 4
Enabled: 0
Active: 0

968 kVAr

Achievable reactive power response



Trial Design Summary

Trials

Over 100 trials were carried out across simulation and real-time environments

- Categories
  - Single-technique trials – validated individual technique behaviour through QUEST
  - Multi-technique trials – tested combinations and coordination
  - Time-series trials – validated QUEST's ability to recalculated benefits and priorities
  - Emergency transitions – simulated state changes and verified mitigation responses
  - ANM Trials – demonstrated flexible services held dispatch

Trial Logging and Validation

- Each trial logged timestamp, system condition, coordination type and success criteria
- Validation included voltage compliance, target achievement and command execution

Test Number	Profile Name	Priority Order	Date	Time Period	Activation
1.1	CDR 100	CDR, SmSt, NEM, TS	27/07/2025	08:41-08:46	Sim, QUEST
1.2	CDR 75	CDR, SmSt, NEM, TS	27/07/2025	08:52-08:57	Sim, QUEST
1.3	CDR 50	CDR, SmSt, NEM, TS	27/07/2025	09:04-9:10	Sim, QUEST
2.1	CDR 100, SmSt 100	CDR, SmSt, NEM, TS	27/07/2025	1401-14:06	Sim, QUEST
2.2	CDB 100, SmSt 100	CDB, SmSt, NEM, TS	27/07/2025	14:07-14:12	Sim, QUEST
2.3	SmSt 100, CDR 100	SmSt, CDR, NEM, TS	27/07/2025	14:13-14:17	Sim, QUEST
3.1	CDR 100, SmSt 100, NEM 100	CDR, SmSt, NEM, TS	07/09/2025	12:51:00-12:55	Sim, QUEST
3.2	CDR 100, NEM 100, SmSt 100	CDR, NEM, SmSt, TS	15/07/2025	09:38-09:45	Sim, QUEST, CLASS
3.3	SmSt 100, CDR 100, NEM 100	SmSt, CDR, NEM, TS	15/07/2025	09:50-10:01	Sim, QUEST, CLASS

Trial Plan

Single Technique Trials

Purpose

- To validate the performance of individual QUEST functionalities under live network conditions

Objective

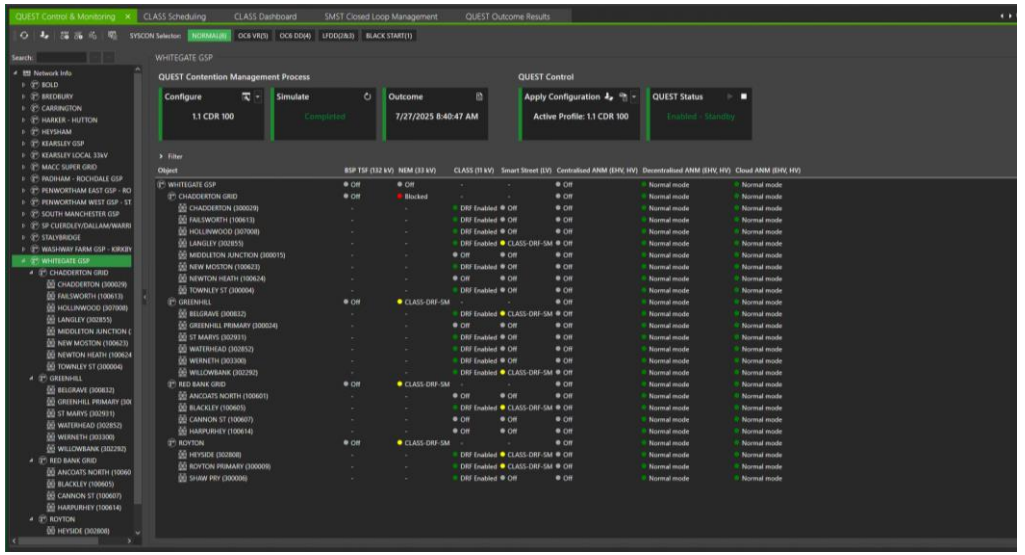
- Confirm each technique operates correctly when activated through QUEST.
- Ensure voltage compliance and target achievement without conflicts.

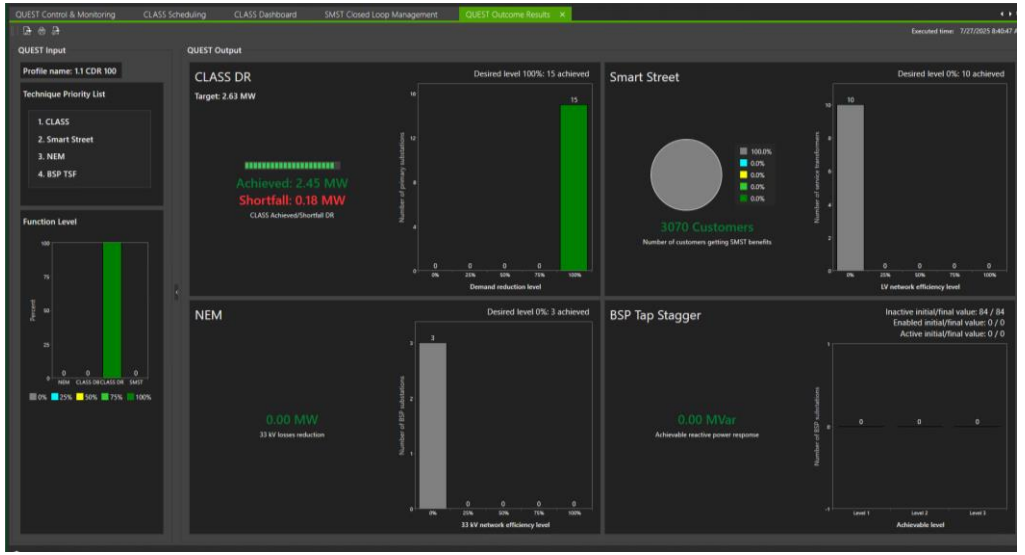
Trial

- Isolated (other techniques disabled) & Integrated mode (other techniques set to 0%)
- CLASS Demand Reduction and Boost at 25%, 50%, 75%, and 100% levels.
- Smart Street CVR applied at LV networks.
- NEM tested for 33kV loss reduction.
- Tap Stagger tested for reactive power absorption.

Outcome

- CLASS DR/DB achieved all target reductions/increases without voltage violations.
- Smart Street delivered CVR benefits while maintaining statutory limits.
- NEM reduced losses measurably at BSP level.
- Tap Stagger confirmed reactive power absorption

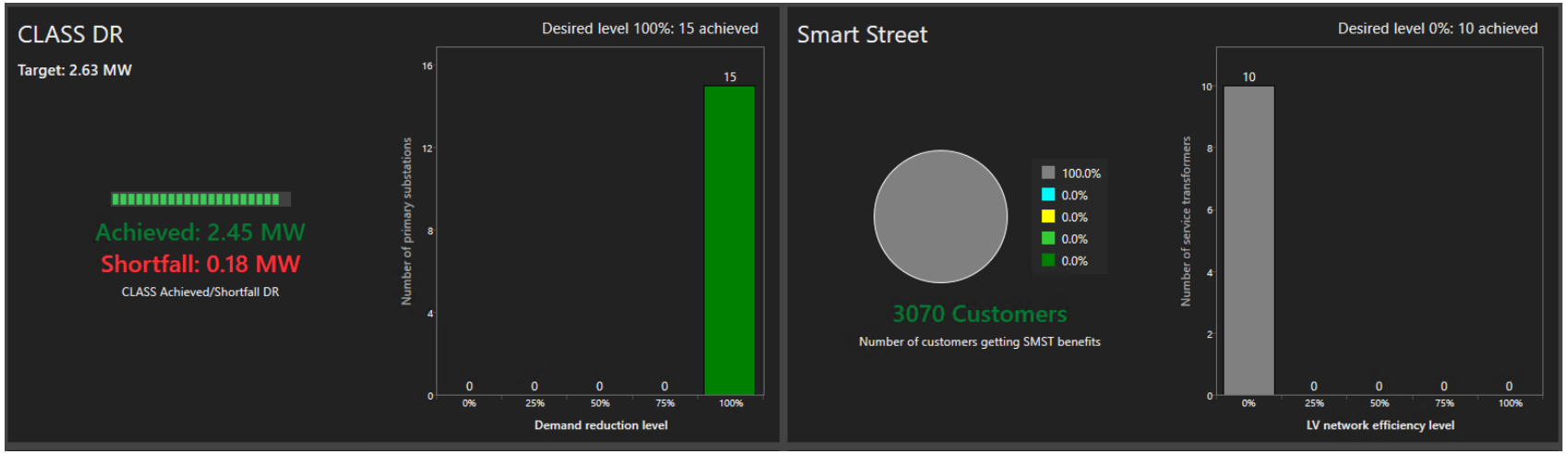




Single Technique Trials - Example

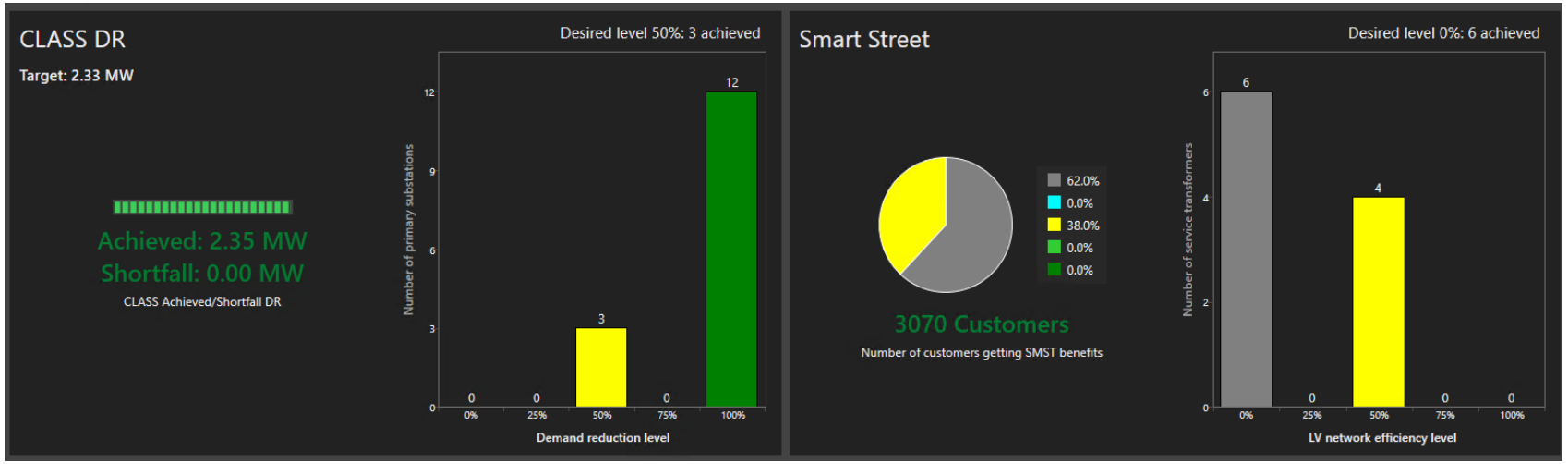
CLASS DR 100

CLASS priority 1 – 100%
All the available system benefit applied to CLASS DR as target not met



CLASS DR 50

CLASS priority 1 – 50%
With target met, benefit observed at priority 2 technique Smart Street



Demonstrates QUESTs logic of fulfilling the highest priority objective first, then distributing additional benefit according to defined priority order.

Remaining sites placed into their Safe Modes ensuring voltage compliance was maintained throughout.

Multi-Technique Trials

Purpose

- To validate QUEST's ability to coordinate multiple techniques simultaneously and optimise system benefits.

Objective

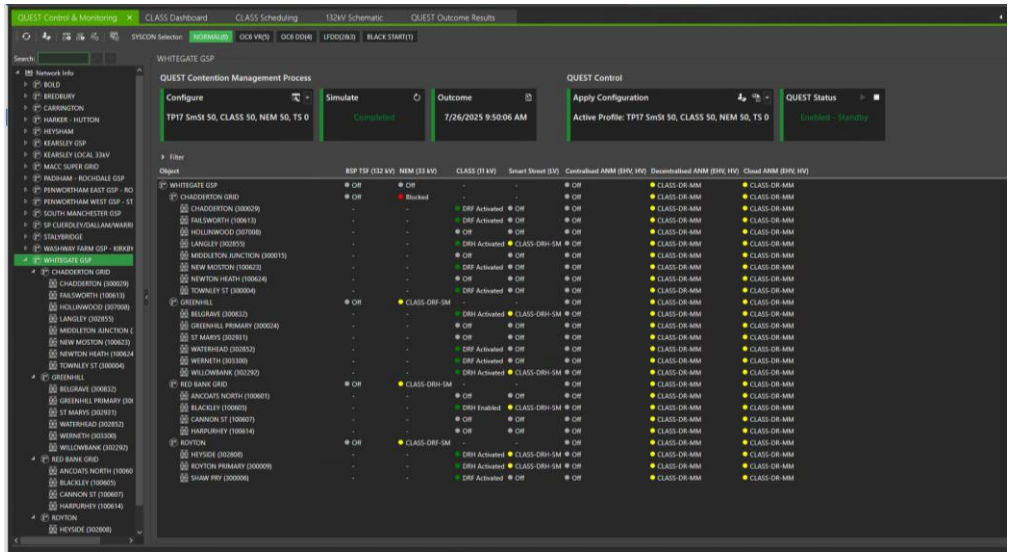
- Test proactive and responsive coordination logic using Technique Priority Lists and Function Levels.
- Ensure safe mode logic prevents voltage violations during combined activations.

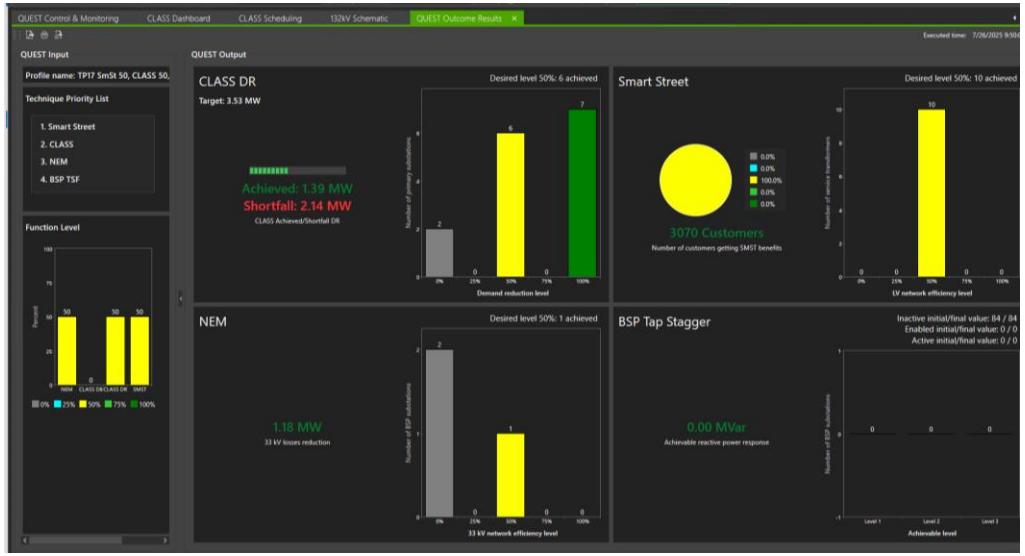
Trial

- Two-technique tests: CLASS + Smart Street at varying priority levels (100%, 75%, 50%).
- Three-technique tests: CLASS, Smart Street, NEM in different priority orders.
- Time-series trials: Dynamic switching between profiles without manual intervention.

Outcome

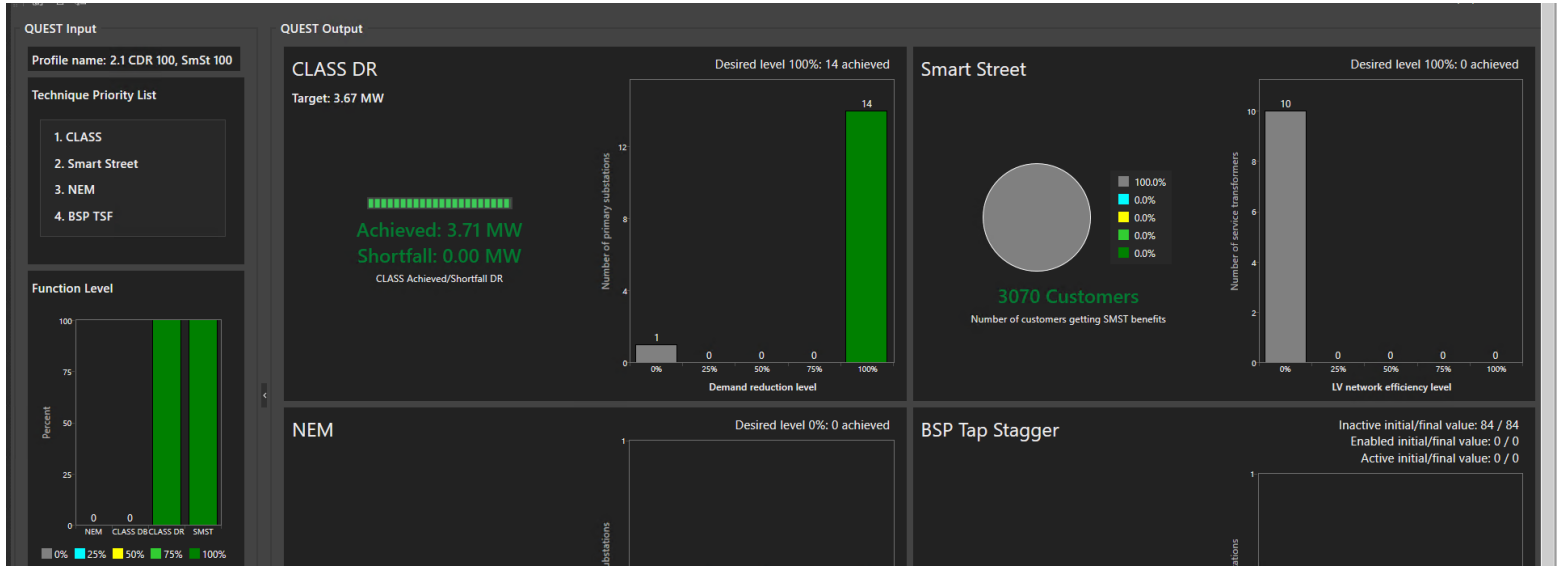
- QUEST successfully allocated benefits based on priority and function level.
- Safe mode logic prevented conflicts and maintained compliance.
- Dynamic recalculation confirmed smooth transitions between configurations.
- ANM mitigation modes activated correctly during multi-technique actions.



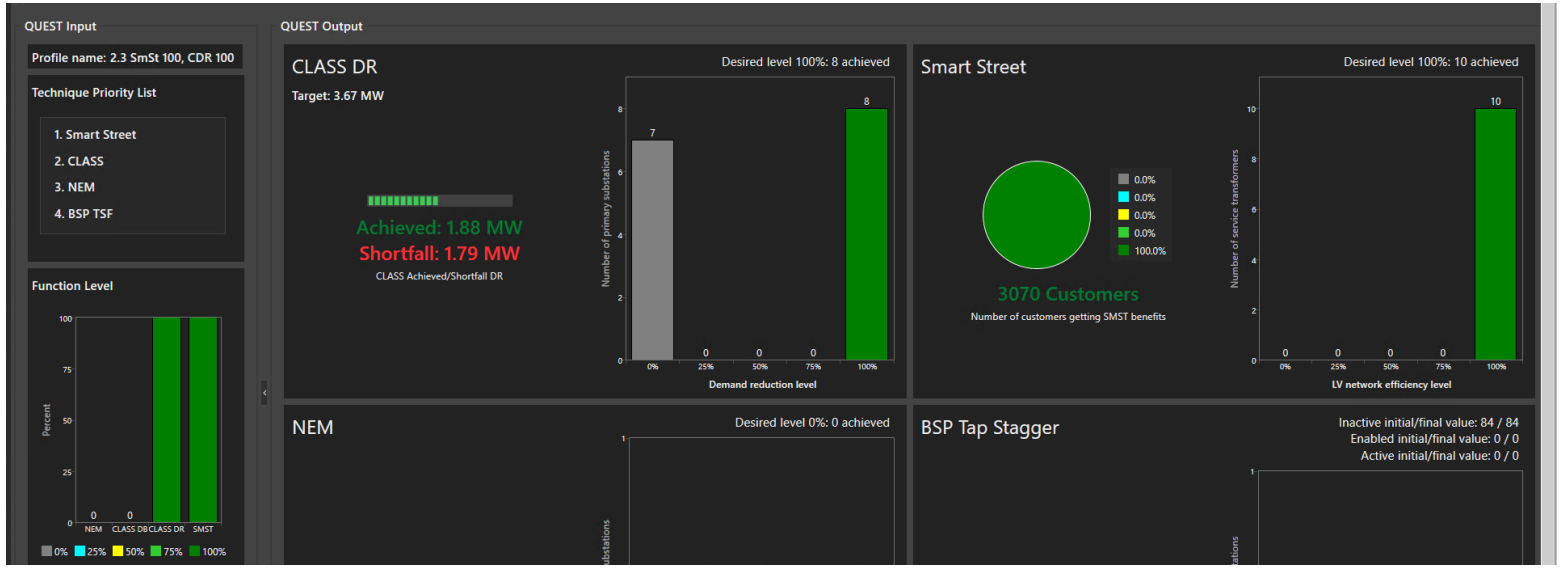


Coordination Example – Two Techniques

Test 1
CLASS DR 1, SmSt 2
Both at 100%

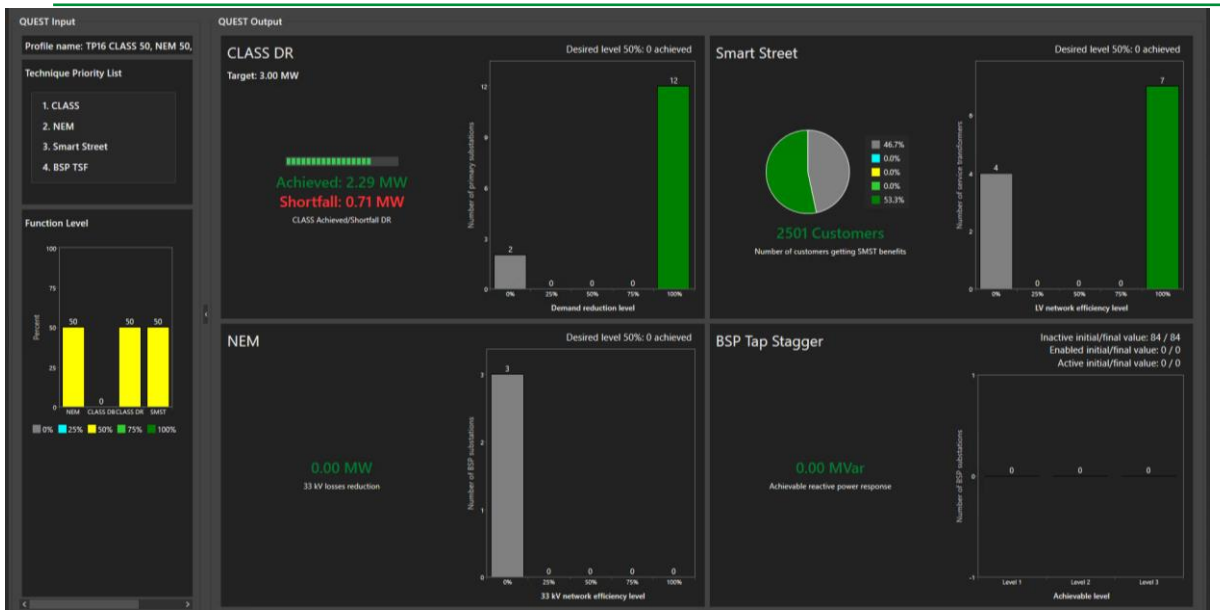


Test 2
SmSt 1, CLASS DR 2
Both at 100%

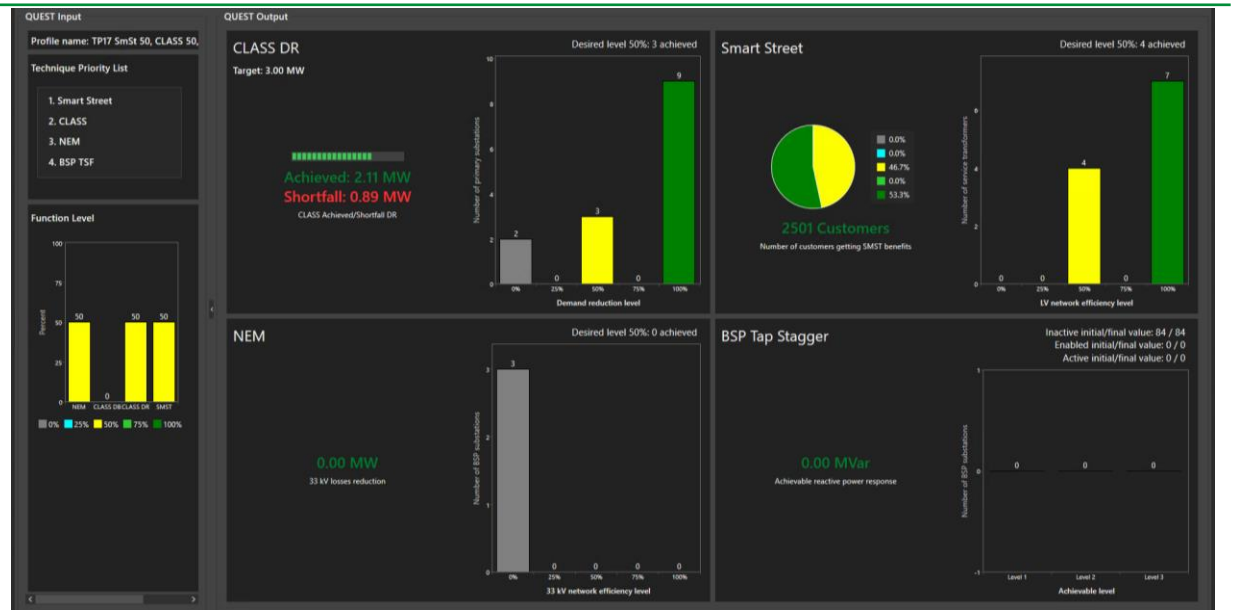


Demonstrates at 100% function level technique priority lists has successfully allocated maximum benefit to CLASS before SmSt in test 1 then maximum Smart Street available in test 2 before passing remaining benefit to CLASS

Coordination Example – Three Techniques



Test 1
CLASS, NEM, SmSt
all at 50%



Test 2
SmSt, CLASS, NEM
Both at 50%

Test 3
NEM, CLASS, SmSt
Both at 50%

Demonstrates at 100% function level technique priority lists has successfully allocated maximum benefit to CLASS before SmSt in test 1 then maximum Smart Street available in test 2 before passing remaining benefit to CLASS

Time-Series Trials

Purpose

- Designed to test QUESTs ability to dynamically adjust coordination and priorities during live operational as system conditions change.

Objective

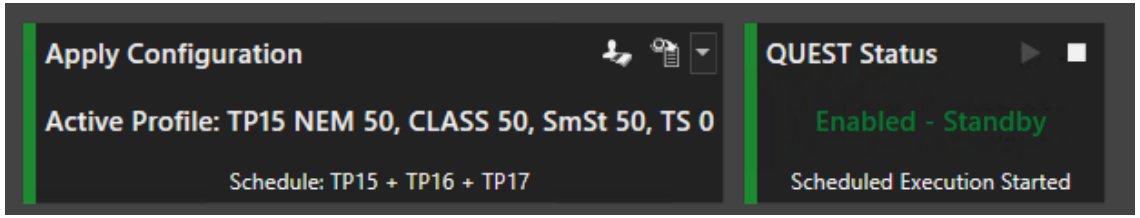
- Validate QUEST can seamlessly transition between configurations, reapply logic and optimise benefits in real time without voltage violations and CE input.

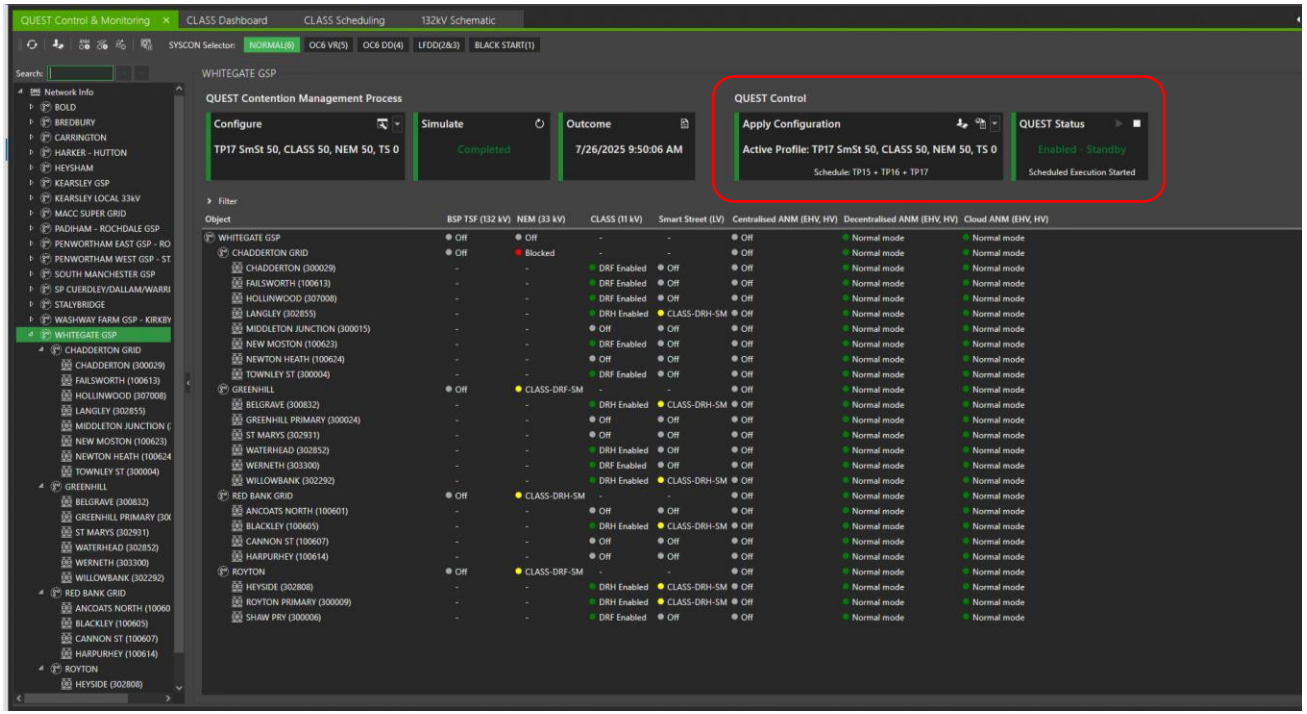
Trial

- Simulate multiple profiles using time-series functionality. For example, running test profiles below without manual intervention.
  - Test 1 – NEM 50, SMST 50, CDR 50 activated 10:05 -10:15
  - Test 2 – CDR 50, NEM 50, SMST 50 activated 10:15 -10:25
  - Test 3 – SMST 50, CDR 50, NEM 50 activated 10:25 -10:35

Outcome

- QUEST dynamically adjusted priorities and coordination during live operation with no manual intervention
- Safe mode logic and updated function levels in real time
- Resulted confirmed that QUEST transitioned smoothly between configurations whilst maintaining voltage limits and maximising system benefits





Reactive Power Support

Purpose

- Demonstrate QUESTs ability to deliver reactive power absorption at Bulk Supply Points using Tap Stagger Functionality.

Objective

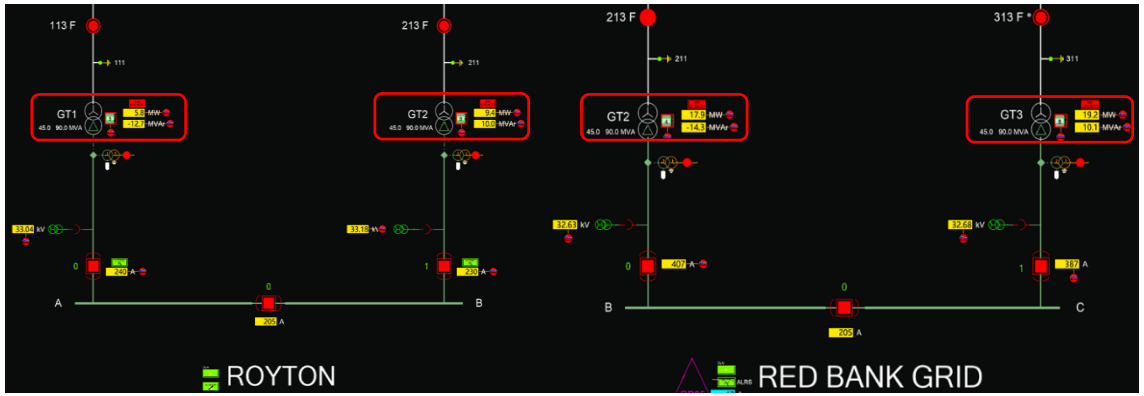
- Validate that QUEST can correctly enable Tap Stagger at the configured function level, maintain system stability, and coordinate with other techniques without conflict
- Demonstrate the level of reactive power response achievable through tap staggering at BSP's

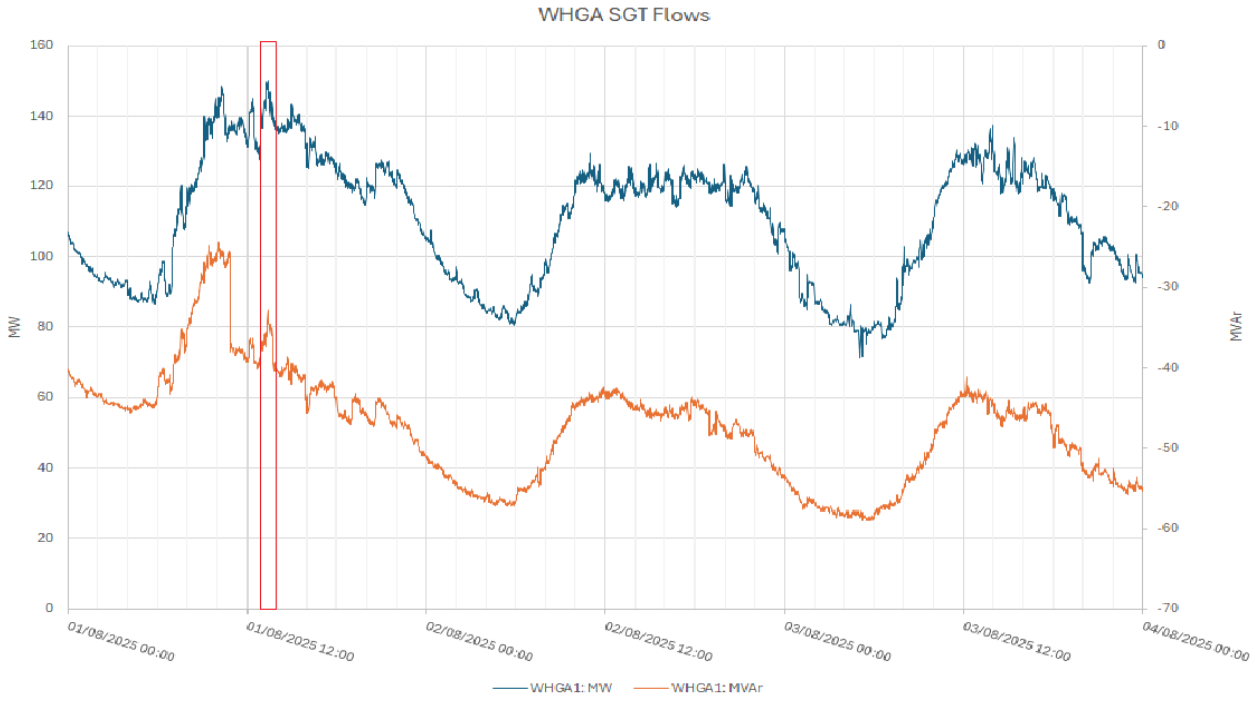
Trial

- Demonstrate QUEST's operational logic by performing isolated BSP TSF test through QUEST
- Four BSP's within Whitegate GSP group were staggered four tap positions apart (TS2 in QUEST).

Outcome

- Across the four BSP sites, the effect was visible at GSP level
- Analysis of Whitegate GSP data from NESO confirmed an increase of 10MVAr with all four BSP's 4 taps apart. Whilst not large in isolation, scaled across all GSPs would result in a significant response.
- Modelling on SGS consultancy model digital twin also seen a similar level of expected response.





Emergency Mode Trials

Purpose

- Designed to test QUEST ability to respond to changes in system state by transitioning between normal and emergency conditions.

Objective

- Ensure QUEST correctly applies mitigation modes to voltage control techniques, sends appropriate commands to external systems and maintains network stability during these critical transitions.

Trial

- Simulated manual activations of the following:

  OC6 Voltage Reduction
  OC6 Demand Disconnection
  LFDD (Low Frequency Demand Disconnection)

Digital twin used to simulate events

Outcome

- QUEST responded quickly and correctly when moving between normal and emergency system states. All in cases, QUEST applied appropriate mitigation modes, locked or disabled relevant techniques.

  LFDD-MM Prevents ANM from releasing curtailed demand
  OC6-DD-MM Locks transformer taps and disables NEM/SmSt
  OC6-VR-MM Reduces voltage without conflicting with NESO instructions
  CLASS remained in its current state unless inhibited

Object	BSP TSF (132 kV)	NEM (33 kV)	CLASS (11 kV)	Smart Street (LV)	Centralised ANM (EHV, HV)	Decentralised ANM (EHV, HV)	Cloud ANM (EHV, HV)
WHITEGATE GSP	Off	Off	-	-	Off	OC6-VR-MM	OC6-VR-MM
CHADDERTON GRID	Off	Blocked	-	-	Off	OC6-VR-MM	OC6-VR-MM
CHADDERTON (300029)	-	-	DRF Enabled	Off	Off	OC6-VR-MM	OC6-VR-MM
FAILSWORTH (100613)	-	-	DRF Enabled	Off	Off	OC6-VR-MM	OC6-VR-MM
HOLLINWOOD (307008)	-	-	DRF Enabled	Off	Off	OC6-VR-MM	OC6-VR-MM
LANGLEY (302855)	-	-	DRF Enabled	OC6-VR-MM	Off	OC6-VR-MM	OC6-VR-MM
MIDDLETON JUNCTION (300015)	-	-	Off	Off	Off	OC6-VR-MM	OC6-VR-MM
NEW MOSTON (100623)	-	-	DRF Enabled	Off	Off	OC6-VR-MM	OC6-VR-MM
NEWTON HEATH (100624)	-	-	Off	Off	Off	OC6-VR-MM	OC6-VR-MM
TOWNLEY ST (300004)	-	-	DRF Enabled	Off	Off	OC6-VR-MM	OC6-VR-MM
GREENHILL	Off	OC6-VR-MM	-	-	Off	OC6-VR-MM	OC6-VR-MM
BELGRAVE (300832)	-	-	DRH Enabled	OC6-VR-MM	Off	OC6-VR-MM	OC6-VR-MM
GREENHILL PRIMARY (300024)	-	-	Off	Off	Off	OC6-VR-MM	OC6-VR-MM
ST MARYS (302931)	-	-	DRH Enabled	Off	Off	OC6-VR-MM	OC6-VR-MM
WATERHEAD (302852)	-	-	DRH Enabled	Off	Off	OC6-VR-MM	OC6-VR-MM
WERNETH (303300)	-	-	DRH Enabled	Off	Off	OC6-VR-MM	OC6-VR-MM
WILLOWBANK (302292)	-	-	DRH Enabled	OC6-VR-MM	Off	OC6-VR-MM	OC6-VR-MM
RED BANK GRID	Off	Blocked	-	-	Off	OC6-VR-MM	OC6-VR-MM
ANCOATS NORTH (100601)	-	-	Off	Off	Off	OC6-VR-MM	OC6-VR-MM
BLACKLEY (100605)	-	-	DRF Enabled	OC6-VR-MM	Off	OC6-VR-MM	OC6-VR-MM
CANNON ST (100607)	-	-	Off	Off	Off	OC6-VR-MM	OC6-VR-MM
HARPURHEY (100614)	-	-	Off	Off	Off	OC6-VR-MM	OC6-VR-MM
ROYTON	Off	OC6-VR-MM	-	-	Off	OC6-VR-MM	OC6-VR-MM
HEYSIDE (302808)	-	-	Off	OC6-VR-MM	Off	OC6-VR-MM	OC6-VR-MM
ROYTON PRIMARY (300009)	-	-	DRH Enabled	OC6-VR-MM	Off	OC6-VR-MM	OC6-VR-MM
SHAW PRY (300006)	-	-	DRH Enabled	Off	Off	OC6-VR-MM	OC6-VR-MM

Object	BSP TSF (132 kV)	NEM (33 kV)	CLASS (11 kV)	Smart Street (LV)	Centralised ANM (EHV, HV)	Decentralised ANM (EHV, HV)	Cloud ANM (EHV, HV)
WHITEGATE GSP	Off	Off	-	-	Off	LFDD-MM	LFDD-MM
CHADDERTON GRID	Off	Blocked	-	-	Off	LFDD-MM	LFDD-MM
CHADDERTON (300029)	-	-	DRF Enabled	Off	Off	LFDD-MM	LFDD-MM
FAILSWORTH (100613)	-	-	DRF Enabled	Off	Off	LFDD-MM	LFDD-MM
HOLLINWOOD (307008)	-	-	DRF Enabled	Off	Off	LFDD-MM	LFDD-MM
LANGLEY (302855)	-	-	DRF Enabled	CLASS-DRF-SM	Off	LFDD-MM	LFDD-MM
MIDDLETON JUNCTION (300015)	-	-	Off	Off	Off	LFDD-MM	LFDD-MM
NEW MOSTON (100623)	-	-	DRF Enabled	Off	Off	LFDD-MM	LFDD-MM
NEWTON HEATH (100624)	-	-	Off	Off	Off	LFDD-MM	LFDD-MM
TOWNLEY ST (300004)	-	-	DRF Enabled	Off	Off	LFDD-MM	LFDD-MM
GREENHILL	Off	LFDD-MM	-	-	Off	LFDD-MM	LFDD-MM
BELGRAVE (300832)	-	-	DRH Enabled	CLASS-DRH-SM	Off	LFDD-MM	LFDD-MM
GREENHILL PRIMARY (300024)	-	-	Off	Off	Off	LFDD-MM	LFDD-MM
ST MARYS (302931)	-	-	DRH Enabled	Off	Off	LFDD-MM	LFDD-MM
WATERHEAD (302852)	-	-	DRH Enabled	Off	Off	LFDD-MM	LFDD-MM
WERNETH (303300)	-	-	DRH Enabled	Off	Off	LFDD-MM	LFDD-MM
WILLOWBANK (302292)	-	-	DRH Enabled	CLASS-DRH-SM	Off	LFDD-MM	LFDD-MM
RED BANK GRID	Off	Blocked	-	-	Off	LFDD-MM	LFDD-MM
ANCOATS NORTH (100601)	-	-	Off	Off	Off	LFDD-MM	LFDD-MM
BLACKLEY (100605)	-	-	DRF Enabled	CLASS-DRF-SM	Off	LFDD-MM	LFDD-MM
CANNON ST (100607)	-	-	Off	Off	Off	LFDD-MM	LFDD-MM
HARPURHEY (100614)	-	-	Off	Off	Off	LFDD-MM	LFDD-MM
ROYTON	Off	LFDD-MM	-	-	Off	LFDD-MM	LFDD-MM
HEYSIDE (302808)	-	-	DRH Enabled	CLASS-DRH-SM	Off	LFDD-MM	LFDD-MM
ROYTON PRIMARY (300009)	-	-	DRH Enabled	CLASS-DRH-SM	Off	LFDD-MM	LFDD-MM
SHAW PRY (300006)	-	-	DRH Enabled	Off	Off	LFDD-MM	LFDD-MM

Activate Network Management Trials

SP Electricity North West

Purpose

- To confirm QUEST can coordinate with ANM systems and prevent conflicts during voltage optimisation. The trials ensured that actions like demand reduction or boost were not negated by ANM releasing generation or flexible demand .

Objective

- Implement and test mitigation modes, verify signal transmission via two ICCP setups, and confirm ANM response. Additional testing explored how different ANM configurations best respond to QUEST signals.

System Overview

- Two ANM systems were integrated into QUEST:

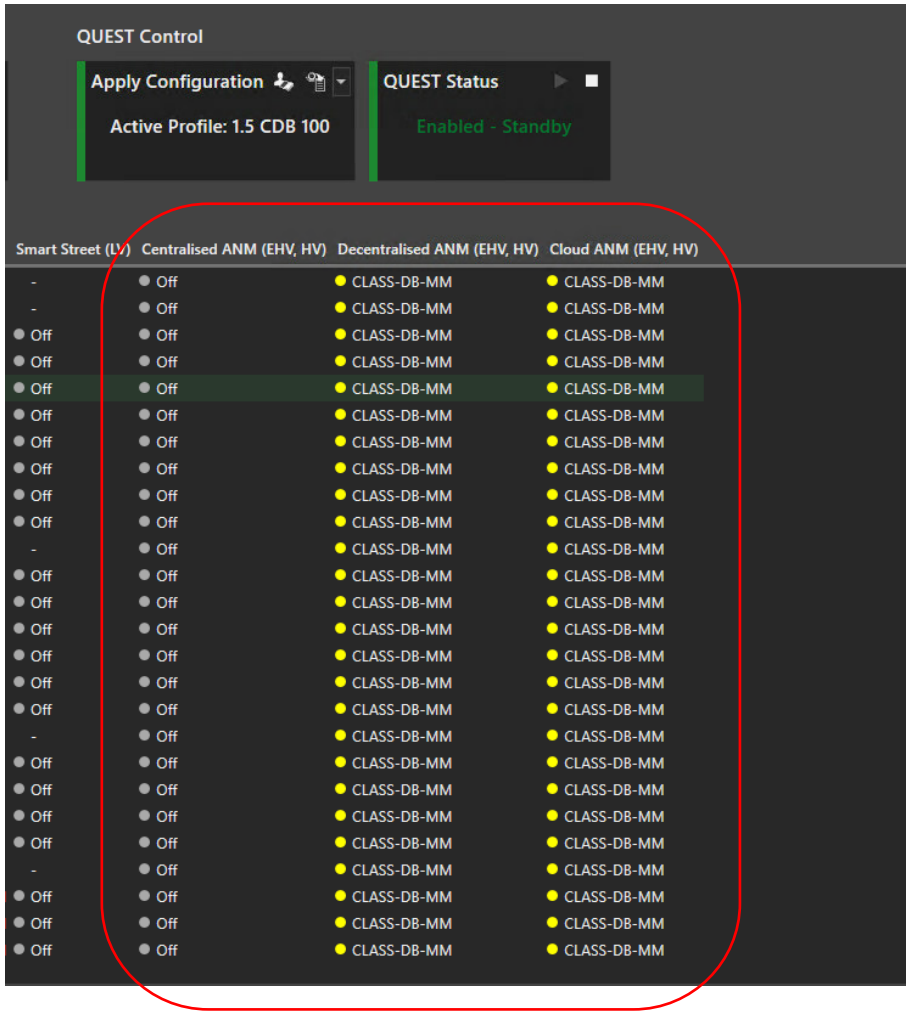
  Decentralised ANM– Simulates real-time DER control for thermal constraint management.

  Cloud ANM – Simulates flexibility service dispatch for day-ahead and intraday scenarios.

Both systems were configured to accept QUEST commands via ICCP and adjust their operating profiles accordingly:

Export Hode Mode - Prevents DER export increase during CLASS demand boost.

Import Hold Mode – Prevents DER import increase during CLASS demand reduction.



Activate Network Management Trials

Operational Logic

Normal mode:

- If power flow > trim threshold → DER curtailed.
- If power flow < release threshold → DER released.

During QUEST trials:

When Hold Mode was active, ANM ignored the release threshold and maintained DER at curtailed levels until QUEST actions were complete.

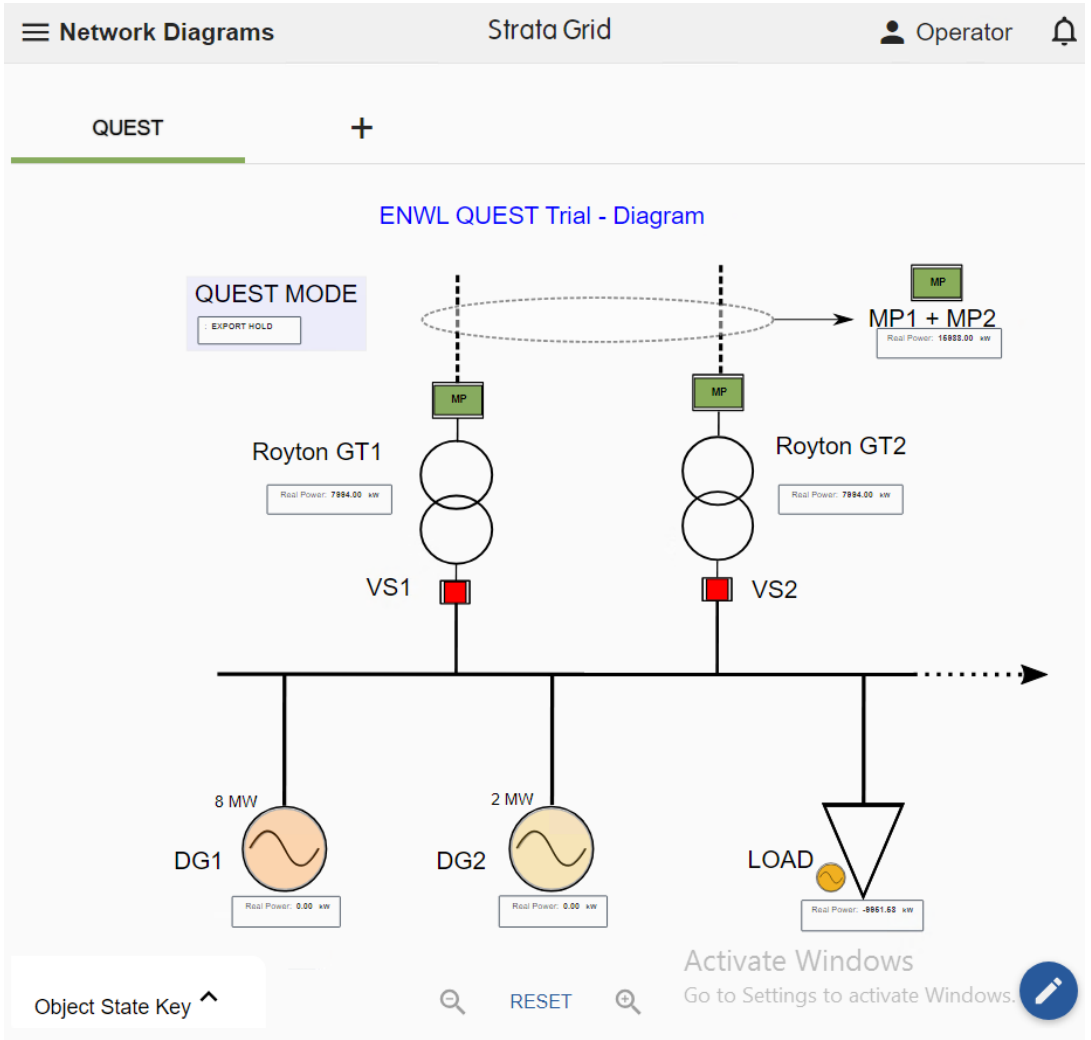
Once CLASS actions ended, Hold Mode was removed, and ANM resumed normal behaviour, releasing DER export/import as appropriate.

Trial Execution

- Tested conflict scenarios (no hold mode) vs resolution (hold mode active).
- Signals sent via ICCP to SGS ANM systems.

Observed Performance

- Hold Mode preserved QUEST benefits.
- ANM resumed normal operation after QUEST actions.



Trial Results Summary

SP Electricity North West

Success

- Trials demonstrated QUESTs ability to successfully optimise conflicting voltage management techniques and maximise outputs
- Trials validated both proactive and responsive coordination logic
- Emergency transitions executed without errors or unintended interactions

CLASS DR/DB

- CLASS DR trails at 25, 50, 75 and 100% levels all achieved their targets
- CLASS DB trails confirmed system demand increased without voltage violations
- Enhanced scheduling and tap control contributed to consistent performance

Smart Street

- Operated in Normal (CVR) and safe modes depending on coordination context
- Trials showed voltage optimisation across LV networks without breaching voltage limits

NEM Loss Reduction

- NEM showed measurable 33kV loss reductions
- Voltage increases at BSP's were coordinated to avoid conflicts with other techniques

ANM

- Trials demonstrated QUEST interfaced with ANM systems, flexible services held dispatch as instructed by QUEST
- ANM system correctly transitioned into mitigation modes during emergency modes
- No unintended releases or conflicts observed during trials

Lessons Learned

SP Electricity North West

Importance of Accurate Priority List and Function Level Blend

- Priority list and function levels central to QUEST coordination logic
- Trials demonstrated that small changes in either can significantly affect outcomes

Communication Loss Handling

- Trials highlighted need for robust fallback mechanisms in case of ICCP or device comms failures
- QUEST must gracefully degrade or hold states when real-time data is unavailable
- Logging mechanisms were effective in identifying and helping resolving issues during trials

Operator Training

- Control engineers and support staff need familiarity with QUEST and its features inc regular refresher training
- Having common pool of trained resource significantly helped with trial phase

Integration with External Systems Requires Coordination

- ANM Systems, Smart Street relays and CLASS schedulers must be aligned with QUEST logic
- Trials showed that coordination across vendors and platforms is achievable but requires planning and testing

Conclusion

SP Electricity North West

QUEST Trial Phase Successfully Validated Core Functionality

- All major use cases and coordination scenarios were tested
- QUEST demonstrated reliable, real-time coordination across multiple techniques

Supports DSO Flexibility and NESO Services

- Enables dynamic voltage control across LV and HV networks
- Complies with NESO requirements for LFDD, OC6 as well as commercial services CLASS DR / Reactive power

Delivers Tangible Customer and Network Benefits

- Reduces losses, improves voltage compliance and enhances service reliability
- Smart Street and CLASS trials confirmed measurable customer benefits

10 Minute Comfort Break

SP Electricity North West

The Project

Refresh – Why and What did we set out to do

Inform – The What and How of what we did and

- Why we are confident to have made the previous statement
- Supported by our project Partners

Learn - What lessons can we take, to make future innovation better

Use - What are SP ENW plans to use QUEST in future (and issues therein)

Lessons – Partner views

Challenges – from project perspective

Infrastucture major challenges

- Access for and Remote support of virtual machine
- Resource challenges (noncore project teams, from across partners)

QUEST System Installation & Maintenance

- Building and testing system, whilst waiting for final infrastructure to be completed
- Ability to train SP ENW team, whilst waiting for final infrastructure to be completed
- Adaptation for BaU functions lost in design change (e.g. Network Model, forecasting updates)
- Access for configuration, support, maintenance and issue resolution
- Multi party configuration of system links (ICCPs, certificates, firewalls & ports)
- Working within wider IT compliance framework, whilst still delivering for project timelines

Lessons – from project perspective

- Only a limited number of software issues identified during tests and trials
  - Assessed and Resolved or Mitigated with learning captured for BaU
  - Some software issues specifically tied to performance of the Project infrastructure (memory/ latency)
- Team working (mostly via TEAMS)
  - Hard but possible to get disparate resources together to resolve issues
  - Regular pre planned weekly sessions, including additional real time support and resolution
  - Multi partner working, especially on initial project phases
- Confidence with QUEST performance during trials, and confidence in steps required to move to BaU

Next Steps – QUEST BaU Design

- QUEST BaU design – Work in progress
  - Timeline Discussion: Establishing milestones for QUEST BaU design
  - Starting Point: All lessons learned from the current QUEST project will guide BaU design
  - Inputs for Design:
    - Lessons Learned Reports & potential QUEST enhancements listed within them
    - QUEST Functional Requirements
    - “For Production” Features – support for enterprise environment
    - NESO Regulation Changes & CLASS updates to support new requirements

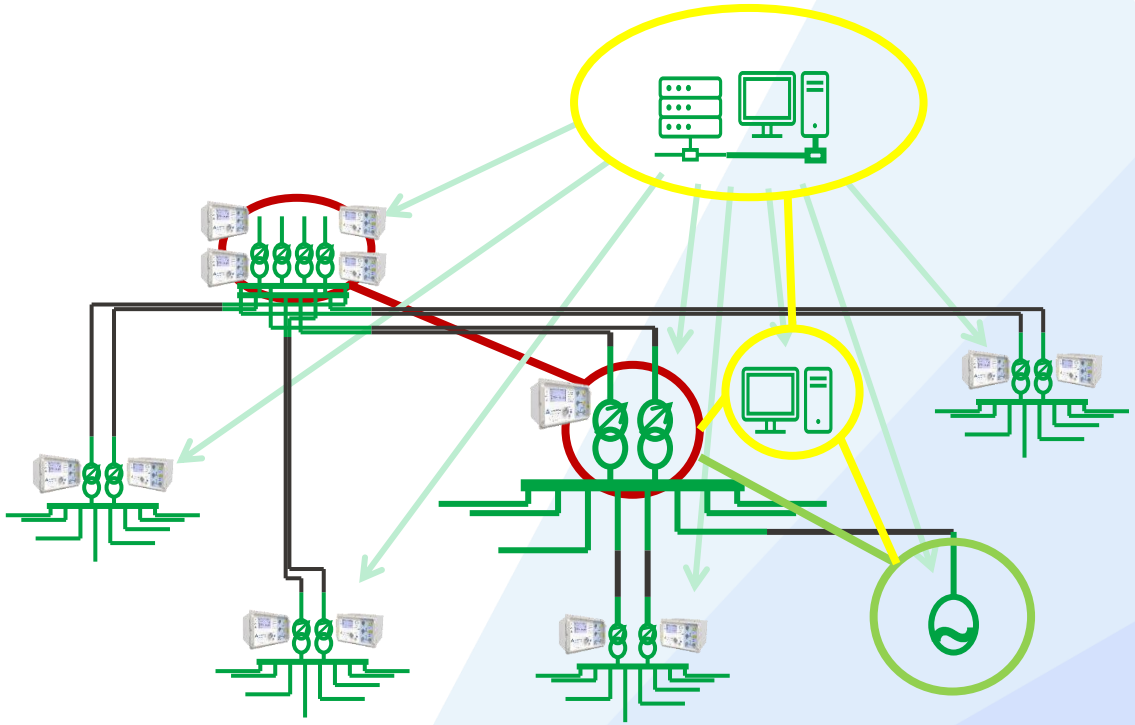
Key learnings

- Our expertise in Voltage Control was a key strength and by applying these principles helped unlock greater value and supported the delivery of a strong and successful project.
- Strong engagement and collaboration is key to delivering a successful outcome.
- All contributors brought valuable insights and by closely coupling delivered shared success.
- Early project engagement and upfront focus is key to delivering successful outcomes.

Fundamentals

Potential Next Steps and Follow-on Opportunities (QUEST Inspired)

- Explore how overarching control could mitigate tapchanger limits and Maximise the number of available Tap positions
- Explore how tapchanger based AVC could interact with generator AVR in different modes (P-Q Vs P-V)
- Explore how hierarchies of control can work together and extend to include AVC…



Fundamentals

Lessons Learned –Technical

Design, delivery, innovation, tools & systems…

- Witnessed FAT might have been more useful instead of demonstration
- **Secure ICCP set-up proved to be challenging**
- ICCP is a reliable protocol for communication between different ICCP vendors
- **Increased test management & end-to-end solution testing**
- Importance of clear method statements
- QUEST integration with representative UK DNO ANM system proved successful

Lessons Learned – Non-Technical

Project Management, processes, stakeholder engagement…

- **Duration of approval processes** such as the RFC process (for setting up new user accounts etc.)
- **Prioritisation of innovation projects** within DNOs
- Document review times
- Document review process and **agreement on specifications** (early alignment necessary)
- Technical document complexity and length
- **Time estimate for tasks** such as the (Secure) ICCP set-up
- **Frequent staff changes** impacted continuity and knowledge retention
- Improve project handover processes
- **More transparent communication** of changes between all partners
- Weekly meetings proved to be very useful

Celebrating Success

- Very good collaboration with all partners to get the trials over the line
- On the SGS Decentralised ANM and Cloud ANM there has been good support and discussions with SE on interfaces and with SP ENW on deployment patterns
- All partner team members have been responsive to issues coming up during testing and set up meetings to resolve these
- Collaborative working environment has been friendly, respectful and productive
- Overall, there were some great deliverables and a good foundation to build on into the future

SP ENW Lessons

SP Electricity North West

Challenges in getting project delivered

- Cyber > Design Change > changed responsibilities > convoluted access > broader expertise requirement > Scarce resource > Competing priorities > Corporate process
- Hardware was the core everything hung off, direct delay & lost opportunities
- Finding an engaging the appropriate customer

Also, things that went well

- Planned project structure of Use cases, refinement, delivery and end product
- Partnership working, noting that waiting for IT did cause some voids for those not immediately involved

Communication that has been made, and received

- Expected channels – Energy Innovation Summit, Project Deliverables, Website materials
- Alternative Channels – Industry Forums (eg Voltage matters) and debates. CIRED papers

Noting that the project learning and a changing world has changed route to adoption

- Transition to BaU will be more complex than planned. It is technically understood, but Business Case needs to be proven, and funding secured

SP ENW Lessons

QUEST WORKS

- QUEST can control voltage at all Network Levels
- QUEST can optimise voltage across all levels based on priorities set
- QUEST will maximise benefits, once all priorities have been met
- QUEST can integrate with 3rd party customer systems and modify their operation
- QUEST benefits can be verified against modelling with a digital twin model
- QUEST can do this using standard SP ENW network equipment
- Whilst costs have increased, the carbon and business benefits have also increased (The trials have proved more “voltage headroom” that postulated at bid)

Next Steps

The Project

SP Electricity North West

Refresh – Why and What did we set out to do

Inform – The What and How of what we did and

- Why we are confident to have made the previous statement
- Supported by our project Partners

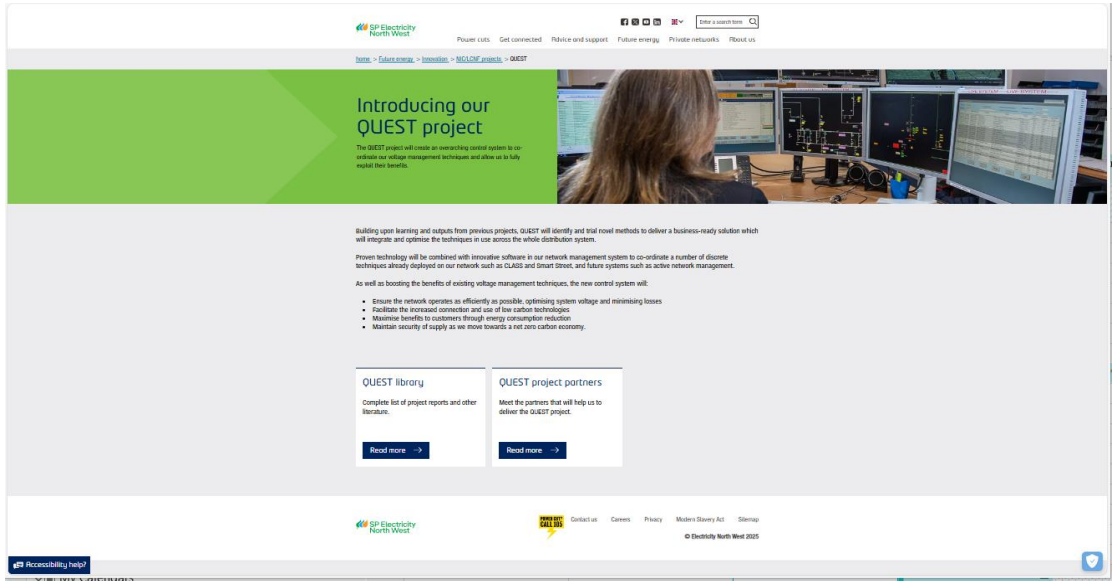
Learn - What lessons can we take, to make future innovation better

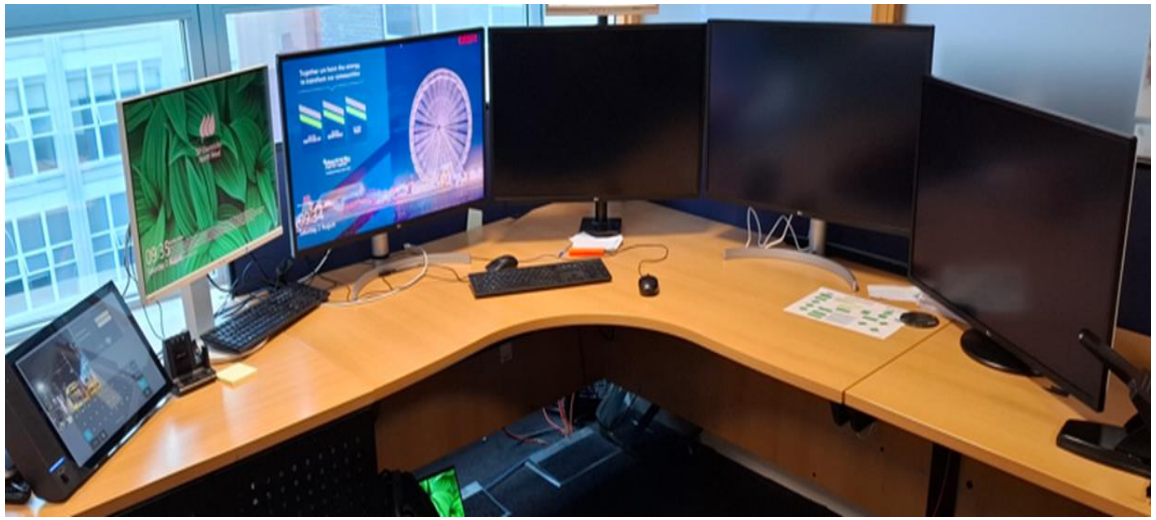
Use - What are SP ENW plans to use QUEST in future (and issues therein)

OVERARCHING CONTROL SYSTEM
QUEST

Next Steps

8. QUEST Final report	To be published Friday 19th December 2025
Formal Closedown	Compliance with Regulations
SP ENW Website	All the projects output has and will be published at: https://www.enwl.co.uk/future-energy/innovation/key-projects/quest/





Scope & Costing	Pre Project work commenced SP ENW & SE
SP ENW Business Case	Late ED2 – ED3
SP ENW BaU	During ED3

SP Electricity North West

Thank You