QUEST
An overarching control system

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OVERARCHING CONTROL SYSTEM
QUEST

QUEST Initial Report – Use Cases

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Project Partners

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APPROVAL

Name	Role	Signature & Date
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Executive Summary

This report introduces 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 detail the Use Cases and scenarios developed as per the project deliverables milestones to identify the potential conflicts and requirements for coordination between existing, independently operating voltage control systems, providing an over-arching system which allows these systems to operate optimally.

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 DNOs, ENWL has introduced innovative voltage optimisation and voltage control techniques.

In ENWL's case, this includes Customer Load Active System Services (CLASS) and Smart Street both of which are used to provide customers with optimum system voltages. Furthermore, Active Network Management (ANM) is another system used to efficiently manage the connection of demand and generation on constrained networks. At present these systems operate independently, meaning there is potential for conflict between the systems, although design considerations are given to avoid such conditions occurring. The QUEST project will introduce an overarching control system to holistically integrate multiple, concurrent system voltage control and optimisation techniques across the whole distribution system to ensure that overall benefits are maximised through coordination of the systems.

To capture potential opportunities for operational optimisation of the various systems, it was necessary to prepare appropriate Use Cases. Use Cases are ideal for capturing likely scenarios where relevant systems would benefit from optimisation. In total, eight Use Cases have been developed and are documented this report. These are a combination of operational scenarios associated with system voltage control and optimisation systems, for example, CLASS, Smart Street, ANM and national events such as OC6 of the grid code. These systems have been examined and are documented here as individual Use Cases. These Use Cases will form the basis of the next step in the project – the development of the architecture options design and network modelling regime. This in turn which leads onto the next project deliverable "QUEST System Design and Architecture Lessons Learned".

This report provides an overview of the Individuals CLASS, Smart Street and ANM systems, their present configuration, mode of operation, and provides an overview of the upcoming project deliverables as outlined within the FSP (Full Submission Proforma). This shows how this project deliverable, "QUEST Initial Report - Use Cases", fits within the rest of the project.

To develop the Use Cases, several workshops took place between the ENWL QUEST team and project partners, totalling over 30 hours of virtual meetings and away days. With multiple draft revisions of individual Use Cases created to ensure likely scenarios, opportunities for optimisation and possible solutions are suitably covered.

This report outlines the approach taken by the project team in developing of the Use Case content and provides a matrix summarising all of the Use Cases and the possible considerations required to be addressed by the QUEST solution. In the final section of this report conclusions have been drafted based on work done to date, including research done in relation to potential opportunities for optimisation and possible solutions. However, all solutions will be the subject of further analysis during the project to model and review architecture options before they are accepted as viable solutions.

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GLOSSARY TABLE

Term	Definition
ANM	Active Network Management
BaU	Business as Usual - refers to business as usual deployment of QUEST following successful trials
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)
ADMS	Advanced Distribution Management System
DNP3	Digital Network Protocol 3
DNO	Distribution Network Operator
EMS	Energy Management System
ENWL	Electricity North West Ltd.
ICCP	Inter-Control Centre Communications Protocol
IEC	International Electrotechnical Commission standards
IED	Intelligent Electronic Device
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

1.0 Introduction

1.1 Purpose of this report

The purpose of this report is to achieve the associated deliverable related to the QUEST Full Submission Application (ENWEN03): to publish a QUEST project Initial Report - Use Cases on the QUEST website by 31st July 2021.

The report firstly introduces the QUEST project and then goes on to document the selected Use Cases prepared to allow for the QUEST system design and architecture options to be considered in the next phase of the QUEST project.

1.2 The QUEST project

In November 2020, Ofgem announced its decision to award us our full funding request of £7.95 million for QUEST, an overarching control system that coordinates existing voltage management techniques to boost available benefits and facilitate increased LCT uptake, via the Network Innovation Competition (NIC). The NIC is an annual opportunity for network operators to compete for funding for the development and demonstration of new technologies and operating or commercial arrangements. To win funding, we demonstrated that the QUEST software is transferrable to other DNOs and will provide environmental benefits, reduce costs, and maintain security of supply as we move towards a low carbon economy.

The project started in January 2021 and will run for four years, completing in April 2025, with a total cost of £9.67 million. We will deliver this project alongside our five Project Partners, Schneider Electric, Smarter Grid Solutions, Fundamentals Ltd, Impact Research and National Grid ESO.

The QUEST project will identify and trial novel methods to holistically integrate multiple, concurrent system voltage control and optimisation techniques across the whole distribution system. The Method will be integrated into the NMS, thus providing the full coordination needed to unlock the available benefits.

In addition, the new holistic voltage control methodology will:

- Ensure the network operates as efficiently as possible, optimising the system voltage to connected customers and minimising losses.
- Further boost the benefits available from existing voltage management techniques.
- Facilitate the increased connection and use of LCTs.
- Maximise benefits to all customers through demand reduction at High Voltage (HV) and Low Voltage (LV).

By providing a means of command arbitration, the QUEST software will ensure that potential clashes are avoided, and overall benefits are maximised through coordination of previously discrete techniques. Furthermore, the QUEST project will provide solid foundation upon which issues associated with conflict resolution, i.e. independent activation of Distributed Energy Resources (DERs), can be addressed.

The QUEST project will explore the coordinated operation of voltage management techniques to enable a reduction of the built-in operating margins, creating capacity for our customers.

The project will also develop and introduce a distribution network-wide, fully coordinated, overarching system to manage voltages, with an appropriate balance between centralised and decentralised control hierarchy.

1.3 Purpose of the Use Cases

This Use Cases are a critical as they prepare the foundation for the future design and architecture specification for the QUEST overarching software. This deliverable is one of nine report submissions to Ofgem providing evidence of the work carried out to meet the project objectives. All deliverable reports must be submitted as per target date outlined in Table 1.

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: • Review of architecture options • 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: • Functional specification for chosen architecture • Functional specification for voltage control methodology • Trial design • 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: • QUEST software development and testing • Power system model development • 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: • Final results from network trials • Final results from modelling trials • Output from the voltage demand relationship research • 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. Completed Close Down Report which complies with the requirements of the Governance Document. Evidence of attendance and participation in the Annual Conference as described in the Governance Document.

Table 1: Project Deliverables

Opportunities to achieve coordination and optimisation of systems and any potential conflict between CLASS, Smart Street, ANM and national events as OC6 of the grid code have been explored and detailed as individual Use Cases. Within this report, eight Use Cases have been developed which outline multiple system behaviours and scenarios. It was crucial to ensure that the Use Case contains the necessary detail required for defining and outlining the QUEST system design and architecture. The Use Cases are to be used as a starting point for the system architects as a basis of their developing the QUEST software requirements. As such, it's likely the Use Cases will be further refined and updated throughout this phase of the project.

1.4 Use Case Development Process

The ENWL project team worked with the project partners responsible for the development of the software to identify how ENWL might want to use QUEST, and to detail this within an appropriate number of Use Cases. These Use Cases outline the likely scenarios of the individual system voltage control and optimisation systems in different operating modes to allow the development and design of architecture options and network modelling requirements.

The Use Case approach was used to help explain how the QUEST system should behave and react within a process. They also help identify possible failure events and situations. In addition, the Use Cases provide a list of goals used to establish the complexity of a system. The template selected for Use Case was proposed by the project partner, SGS, whom have extensive experience in Use Case development on other Industry innovation projects and was thought to be a good fit to the QUEST project.

The Use Cases within this report were developed over thirty hours of virtual workshops carried out and attended by all partners, including Schneider Electric's software development engineers and system architects based in Serbia, Smart Grid Solutions development team based in Glasgow, Fundamentals Ltd design engineers based Birmingham and ESO's network development team based in Warwick. Furthermore, two full-day, deep-dive sessions by the ENWL project team were held to document the QUEST system requirements in terms of QUEST operator functions and User interface. These were valuable sessions as it was important that ENWL make clear to the software developers what is expected of the QUEST functionality and User Interface within the EWNL NMS system.

1.4.1 Challenges in Use Cases development

The main challenge within the development of the Use Cases is that when scenarios and response behaviours were being outlined, although there was a clear understanding of the goal and objective of each Use Case, it was unclear as to how this would be achieved without further in-depth modelling and statistical techniques. Further discussion within the project group concluded that although the method of how these goals and objectives would be achieved is crucial, it was not a priority to describe how this would be achieved with the software and architecture as next phase (detail design and architecture lessons learned) would demonstrate how these goals and objectives would be achieved in this detail. What Use Cases therefore capture are the expectations of users when using the QUEST application. Use Cases typically describe the business processes that could be impacted by the use of the new application and comprise end to end user experience.

1.5 Learning Outcomes during Use Case development

The template of the Use Cases is represented as a sequence of simple steps, beginning with a user's goal and ending when that goal is fulfilled. This approach allows for a smooth transition into the design specification and architecture phase where these Use Cases will be analysed (proved / disproved / updated / replaced) in further detail to help with the development of the design specification within the next deliverable phase of the project. It is, therefore, reasonable to expect these Uses Cases to be further refined over time as the project progresses. In this sense, these Use Cases represent initial cases, and ENWL will publish any meaningful update, including describing the changes throughout the project. The Use Case template allows the designer or developer to update individual Use Cases seamlessly while at the same time archiving notes of the changes made. This is extremely useful when documenting Use Case development and tracking agreed changes throughout the project.

2.0 Background

2.1 The Problem

Effective control of system voltages is crucial to the safe and efficient operation of distribution networks and to provide optimum voltage to connected customers. Methods for controlling system voltages on distribution networks have evolved over time based largely on the historic passive nature of power flows – whereby power flows in one direction, from the transmission network through to demand customers connected to the distribution network – together with the predictable nature of customer demand profiles. The passive nature of the network meant that the design and operation of voltage control solutions, typically via use of transformer tap settings, could be kept simple, with local solutions acting independently with minimal need for overall co-ordination.

This type of voltage control is applied at discrete layers on the distribution network. Many of the voltage control solutions are fixed systems, with local, manual adjustment of transformer tapping equipment, while others are fitted with Automatic Voltage Controllers (AVCs), which vary the voltage dynamically in response to local measurements. In recent years, DNOs have introduced voltage optimisation and Conservation Voltage Reduction (CVR) to provide customers with optimum system voltages. Intelligent network devices and central software are used in combination to change system voltages dynamically. Furthermore, Active Network Management (ANM) has also been deployed to efficiently manage the connection of demand and generation on constrained networks. Usually, the ANM solution needs to address thermal constraints but sometimes voltage constraints may be present.

This changing landscape will result in more areas of the network becoming constrained due to voltage issues. Without significant reinforcement, historic solutions for distribution network voltage control are not well-suited to addressing these needs. Therefore, more economic techniques such as voltage optimisation and ANM will be deployed. The proliferation of discrete voltage management techniques could introduce problems, i.e., when active at the same time and on the same part of the network, it is possible that one technique could counteract another. To mitigate this, DNO's currently design, configure and deploy these techniques with built-in safety margins that provide an operating 'buffer'. This could lead to a reduction in the effectiveness of each technique.

2.2 The Solution

To ensure that all techniques are operated optimally, it is necessary to investigate ways of integrating the various, discrete techniques to create a flexible and co-ordinated system.

Using a modern Network Management System (NMS) and intelligent relays, coupled with innovative software deployed in the control room, QUEST can provide a more optimal way to manage system voltage. Full use of the permissible voltage range is key to the QUEST project providing a more economic system of electricity distribution than is currently possible using conventional voltage control solutions.

This improved optimisation of system voltage will provide significant benefits to customers and the environment through increased capacity for new connections, energy savings for customers, and reduction in network losses.

Before setting out on the design and architecture specification for this project a range of Use Cases is to be developed, capturing how the QUEST overarching control will be expected to work (e.g. where a clash is predicted, which system is to be prioritised and when and how the voltage optimisation systems already in place will interact with each other). The Use Cases will also identify potential areas of conflict and help designers and developers explore solutions to overcome them. Each of the Use Case combinations within this report details the overall system's behaviour as it responds to requests from ESO or potential network failure scenarios.

2.3 What is QUEST?

To cater for the subsequent increase in electricity demand and generation caused by decarbonisation targets, DNOs have investigated and deployed techniques such as Customer Load Active System Services (CLASS), Smart Street and Active Network Management (ANM) optimisation systems. Whilst these systems have proven successful in helping DNO's to manage the network they do have limitations such as:

- They are often applied in isolation of one another and do not operate in a co-ordinated manner.
- It is possible that one technique could counteract another, resulting in reduced effectiveness and potentially failing to maintain operation within acceptable limits.
- They use worst-case planning assumptions, which build in large safety margins, resulting in operation below the theoretical maximum.
- They require a resilient communications infrastructure at all times and are set up to fail safe. Therefore, if there is a communications failure any voltage optimisation or ANM benefit is significantly reduced or removed.

The QUEST project will aim to integrate the above voltage optimisation systems into one overarching, co-ordinated and optimised system, with appropriate balance between centralised (global) and decentralised (zone) control hierarchy. This will enable voltage optimisation for the whole distribution network. By viewing and controlling the whole network, QUEST will co-ordinate the often-competing objectives of these existing systems to ensure optimised operation whilst maximising benefits for customers. In addition, the QUEST software will allow demand and generation to automatically self-adjust in response to changing voltage requirements, creating an innovative self-regulating distribution network.

QUEST Voltage Optimizer is the overarching software system that has the ability to control other individual systems on the network i.e. Enhanced AVC including CLASS, Smart Street and ANM. These systems provide voltage control, thermal constraint management and demand control. Where appropriate, the QUEST Voltage Optimizer will optimise system voltages to provide additional benefits e.g. by reduction of system losses.

2.4 QUEST Team Structure & Partners

The QUEST ENWL team structure and supporting project partners can be seen below in Figure 1 and 2. This structure outlines some of the key people involved with the project delivery and project assurance to ensure all deliverables are met in line with the FSP (Full Submission Proforma).

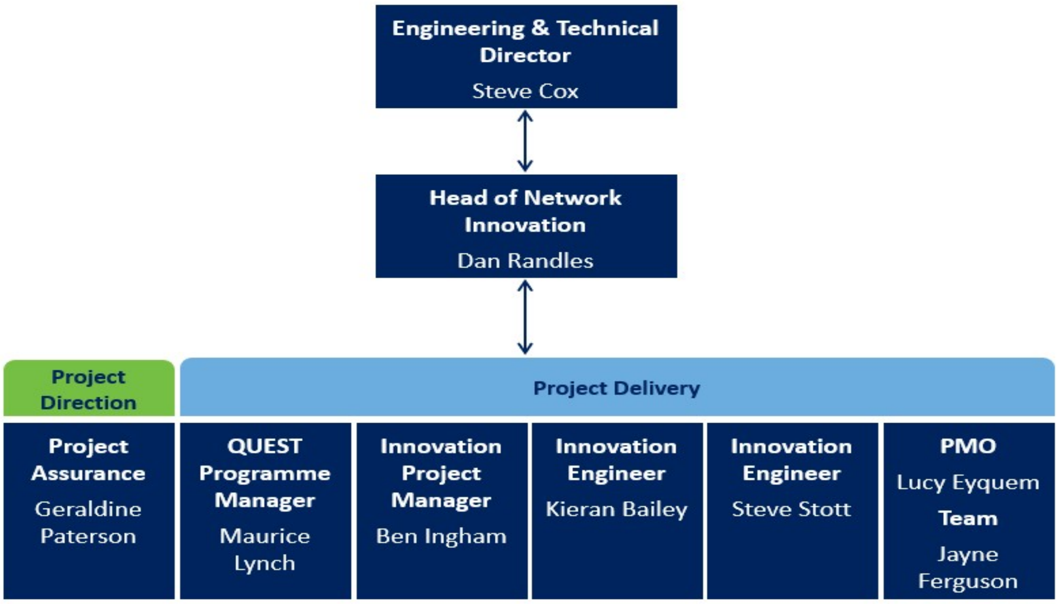

Figure 1: QUEST ENWL Team Structure

Figure 2 below identifies the project partners involved within the QUEST project. These partners were carefully chosen due to their specific skill set and industry experience/knowledge to ensure the successful delivery of the QUEST project objectives.

Figure 2: QUEST Project Partners

3.0 QUEST Objectives

QUEST is the novel application of proven technology combined with innovative software. It will build an overarching system which operates a holistic voltage control methodology for utility distribution networks. QUEST software will coordinate existing and future voltage management techniques, establishing efficient network operation, promoting low-cost connection and use of Low Carbon Technologies (LCTs), to deliver significant customer benefits.

The objectives of QUEST project are:

1. To introduce a distribution network-wide, fully coordinated, overarching system to manage voltages, with an appropriate balance between centralised and decentralised control hierarchy. This will allow Distribution Network Operator (DNOs) to more actively manage voltage profiles across their entire network to remove voltage constraints and optimise operation.
2. To integrate discrete voltage management techniques into an overarching, coordinated and optimised system, enabling voltage optimisation for the whole distribution system, from the Electricity System Operator (ESO) intake to the interface with the domestic customer.
3. By viewing and controlling the distribution system as a whole, QUEST software will coordinate the often-competing objectives of the various, discrete voltage control techniques to ensure optimised operation whilst maximising benefits for customers.
4. The QUEST project will explore the coordinated operation of voltage management techniques to enable a reduction of the built-in operating margins, creating capacity for customers using existing circuit assets and thus facilitating the increased connection and use of LCTs.
5. Under normal operation, ensure the network operates as efficiently as possible, optimising the system voltage to connected customers and minimising losses, based on the interaction of other discrete voltage systems on the network.
6. The QUEST project will also explore how to unlock benefits for National Grid Electricity System Operator (ESO) by providing improved visibility of real-time, embedded generators and other forms of Distribution Energy Resource (DER) and allowing “tuned” responses for demand control and OC6.
7. QUEST software shall maintain statutory voltage limits as per Electricity Safety, Quality and Continuity Regulations (ESQCR) and will ensure no disruption to system commercial contractual agreements, unless under emergency response situations.

8. In the event of loss of system communication, the QUEST overarching control system shall ensure it and any associated discrete voltage systems default to a safe mode setting, to maintain network stability and safety

3.1 QUEST Operational Objectives

QUEST has 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 systems at all times.
3. Enhance operational efficiency.

The QUEST Use Cases have been developed to obtain an initial understanding of the opportunities for optimisation and potential conflicts that may occur between three key voltage control and optimisation systems:

- Enhanced AVC including CLASS
- Smart Street
- ANM

The QUEST project will aim whenever possible to operate network voltages to provide system benefits. Where conflicts have been identified, the role of QUEST software is to ensure the operational objectives are maintained.

The purpose of the Use Cases are to identify opportunities for optimisation of the configuration of the various systems and conflicts, including possible solutions.

As an example, a potential operational conflict between Enhance AVC including CLASS and Smart Street has been identified within the Use Case. If CLASS demand reduction was activated, subsequent operation of Smart Street could counteract the total demand reduction calculated by the CLASS system. This conflict could be resolved by QUEST software if a new voltage setpoint was sent to Smart Street when CLASS is enabled. At this stage of the project it is not possible identify the actual setpoint required until studies are carried out to determine the extent of the conflict, this is the next stage project “system Design & Architecture Lessons Learned”.

3.2 Centralised Overarching Software

A key area of development will be the innovative, overarching control software to allow DNOs to more actively manage voltage profiles across their entire network to remove voltage constraints and optimise operation. The QUEST project is examining a range of Use Cases and architecture options to design the overarching, coordinated and optimised system.

The Use Case development considers the wider QUEST objectives while focusing on the functional requirements of the overarching control software which at a high level include:

1. The QUEST optimizer software module will take an overview of the network, in conjunction with forecasted loadings, to control both new and existing intelligent voltage control devices at substations.
2. The QUEST optimizer software module will continuously monitor the network and adjust its decisions in real-time as conditions change.
3. The QUEST optimizer software module will use the various voltage management techniques available to balance outputs and adjust voltages to meet user-defined objectives.
4. The QUEST optimizer software will be designed to enable objectives to be applied to the distribution system as a whole, or to be configured to meet local needs on specific subsets of the system.

4.0 QUEST Use Cases

The functional Use Cases identified to support development of the QUEST overarching Voltage control system are listed below.

1. QUEST Network Efficiency.
2. Smart Street and Enhanced AVC including CLASS.
3. Smart Street and ANM (Flexible service and connections).
4. Enhanced AVC including CLASS and ANM (Flexible service and connections).
5. Smart Street, Enhanced AVC including CLASS and ANM (Flexible service and connections).

<u>NG ESO responses</u>

6. Smart Street, Enhanced AVC including CLASS, ANM and LFDD.
7. Smart Street, Enhanced AVC including CLASS, ANM and OC6.
8. Smart Street, Enhanced AVC including CLASS, ANM and Deliver Reactive Response.

It should be noted that Optional Downward Flexibility Management (ODFM) was also considered when developing the Use Cases. However, as per the information report provided on the ESO data portal which states ODFM is a time-limited service that will expire 31st October 2021, it was felt that creating an individual Use Case for this service was not applicable.

Dynamic containment which has been highlighted within the ESO Market road map 2025, has also being considered within the Use Cases, this is known as SFR within the CLASS functionally as seen in Use Case No.4. It was felt no individual Use Case is required as this functionally already exists within CLASS and the other Use Cases that include CLASS SRF.

The identified Use Cases will be developed to focus on the functional requirements of the overarching control software which align with the overall QUEST objectives.

4.1 Use Case Development

The selected Use Case template is shown below in Table 2. It was developed with the with the project partners to outline the operational scenarios identified. As part of the Use Case development, a draft set of “Actors” has been created to ensure consistency across the Use Cases.

<table>
<tr><td>Use Case Name</td><td colspan="5">The name of the Use Case being discussed is inserted within here.</td></tr>
<tr><td>Use Case Number</td><td>[e.g. UC1]</td><td>Version</td><td>[e.g. 1.0]</td><td>Status</td><td>[status: e.g. draft, under review, approved]</td></tr>
<tr><td>Use Case Development Owner</td><td colspan="5">[Name of company or partnering company taking the lead and ownership of the Use Case during development is inserted here]</td></tr>
<tr><td>Use Case Description</td><td colspan="5">[Description of the Use Case function, is inserted in here along will all associated individual systems within the Use Case]</td></tr>
<tr><td>Primary users</td><td colspan="5">[Primary users are the stakeholders within the Use Case that are initiating change on to the network]</td></tr>
<tr><td>Secondary users</td><td colspan="5">[Secondary users are the stakeholders within the Use Case that are impacted by change on the network].</td></tr>
<tr><td>Trigger</td><td colspan="5">[A trigger is an event or instruction that initiates the operation of the Use Case]</td></tr>
<tr><td>Preconditions</td><td colspan="5">[These are the conditions that can exist prior to the Use Case trigger event]</td></tr>
<tr><td>Post Conditions</td><td colspan="5">[These are the conditions at the end of the Use Case after the trigger event]</td></tr>
<tr><td>Main Success Scenario
[This section details the steps of the Use case once trigger has been initiated, by outlining conflicts and possible solutions to those conflicts detailed]</td><td>Steps</td><td colspan="4">Actions</td></tr>
<tr><td></td><td>1.</td><td colspan="4">[Describe in the simplest terms what should happen next]</td></tr>
<tr><td></td><td>2.</td><td colspan="4">[Describe in the simplest terms what should happen next]</td></tr>
<tr><td></td><td>3.</td><td colspan="4">[Describe in the simplest terms what should happen next]</td></tr>
<tr><td></td><td>4.</td><td colspan="4">[Describe in the simplest terms what should happen next]</td></tr>
<tr><td>Extensions</td><td colspan="5">[This section details the steps of the Use case once the trigger has been initiated, by outlining conflicts and possible solutions to those conflicts detailed]</td></tr>
<tr><td>Notes and Outstanding issues (if any)</td><td colspan="5">[This section details the steps of the Use case once the trigger has been initiated, by outlining conflicts and possible solutions to those conflicts detailed]</td></tr>
</table>

Table 2: Use Case Template

The Actors describe specific roles and functions within the Use Cases. The actors are intended to relate to the QUEST architecture illustrated in **Error! Reference source not found.**. The list of defined actors used to assist with consistent naming of users involved in the various use cases can be found within Appendix 1.

"Primary Users" and "Secondary Users" in the Use Case templates could be any one of the listed actors. Primary users are actors that play a key role in the use case while secondary users are actors that play a lesser or minor role. For example, considering Use Case 3, the DNO Control Room plays a key role and is listed as the Primary User with ANM DER (Flexible Connections) listed as Secondary Users, as they may be issued with control set points by the Decentralised ANM to reduce import/export.

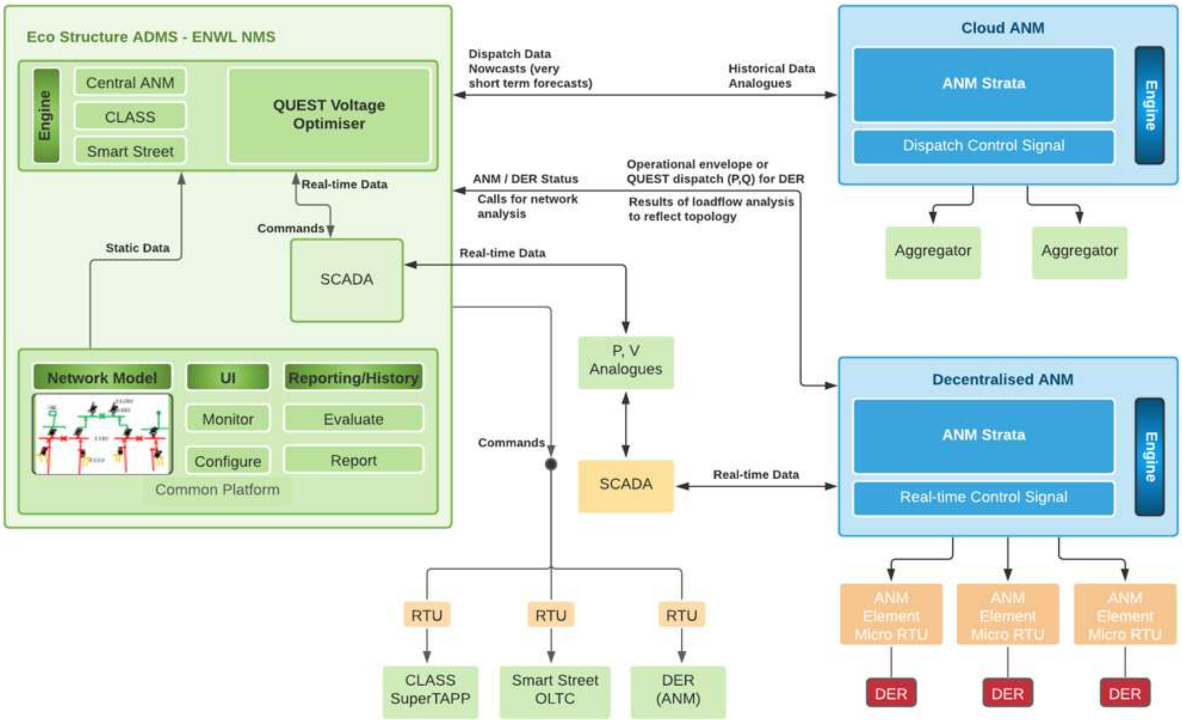

Figure 3: QUEST High Level Architecture

The following sections 4,2, 4.3 and 4.4 of this report provide a brief overview of the functionality of the existing and currently being deployed system voltage control and optimisation systems in use on the ENWL network.

As these systems are the main Actors that fall under the control of the QUEST overarching system, it was important that a description of how these systems currently operate be outlined to provide a better understanding to the reader when reviewing the Use Cases within section 4.5.

4.2 Active Network Management overview

The QUEST high level architecture diagram shows three separate Active Network Management (ANM) systems, the Central ANM NMS, Decentralised ANM and Cloud ANM.

- The Central ANM NMS is an existing system that is part of the Advanced Distribution Management System (ADMS). This Central ANM NMS system monitors the distribution network for thermal limit threshold violations and voltage violations and issues set points to DER with flexible connection agreements to modify their import/export to remove the limit violation. In addition, the Central ANM NMS can control the dispatch of DER which have contracted to provide flexible import/export services at pre-agreed prices. The Central ANM NMS uses a merit order list provided by the external Merit Order Management System (MOMS) to dispatch DERs in the most cost-effective way when required. Also, the Central ANM NMS identifies potential future constraint violations within a configurable look ahead period based on forecasted generation and demand levels and produces a list of expected constraint violations together with the associated DERs that could potentially be used to resolve each constraint violation. The output is sent to the MOMS for processing and providing the updated merit order list that is used in real-time for constraint violation mitigation.
- The Decentralised ANM is a new ANM system to be established as part of the QUEST project. This ANM system is to reflect other standard ANM systems introduced by other UK DNOs for the thermal constraint management using DER with flexible connection agreements. The detailed design of this ANM system has still to be established, however, the system will employ a merit order when controlling DER to manage network constraints. The functional nature of the decentralised ANM is similar to that of the Central ANM NMS. The Central ANM NMS and Decentralised will operate on different parts on the ENWL distribution network for the QUEST project.
- The Cloud ANM is a new system to be established as part of the QUEST project. The Cloud ANM will allow the DNO to make use of DER flexible services offered by Flexibility Service Providers (FSP) such as aggregators to manage forecast network constraints. The availability and price of flexible services is established ahead of need and dispatch instructions are issued to FSPs ahead of the forecast requirement. Cloud ANM dispatch optimisation is used to ensure economic efficiency. Hence, unlike the Central ANM NMS and Decentralised ANM, the Cloud ANM is not a real time operational system. Developing markets for FSP services to DNOs is recent in the UK and flexibility service products are still being developed and trialled. The design for the Cloud ANM has still to be established including the service products to be trialled, what sort of trading arrangements or system

is to be established and what ENWL systems and interfaces will be required for contract management, settlement services and performance monitoring/reporting etc. Hence in the use cases developed here Cloud ANM flexible services is indicated as an extension for future development and is not include in the main use cases.

In the use cases, the term ANM is used to represent all three ANM systems described above noting that Cloud ANM will be a future extension. All three ANM systems described operate independently of each other. The Central ANM NMS will operate on different areas of the distribution network from the Decentralised ANM and Cloud ANM.

4.3 Enhanced AVC including CLASS overview

4.3.1 Enhanced AVC (EAVC)

The Enhanced AVC (EAVC) relay was designed to provide additional functionality over and above the traditional relays. In addition to providing voltage regulation, the EAVC had built-in intelligence to allow it to handle scenarios where the level of connected generation was equal to or in excess of the local demand, leading to a fluctuating power factor etc, as the level of net demand varied throughout the day. Furthermore, the relay also had the built-in capability to deliver the CLASS functionality without any additional intelligent devices being required on-site, as was the case with the original CLASS project.

4.3.2 CLASS

CLASS (Customer Load Active System Services) is a system designed to increase the capacity of the electricity network. It is a low-cost solution which uses voltage control to manage electricity consumption at peak times and provides the Electricity System Operator (ESO) with an alternative source for a number of ancillary services, while still providing customers with the same standard of service. CLASS is delivered as a unique function of the Enhanced Voltage Control Relay Super Tapp.

The ability to manage peak demand and offer alternative sources for ancillary services provides a useful tool to help meet the increasing demand for electricity and brings a number of other advantages such as:

- Facilitates the connections of low carbon technologies onto the electricity network such as heat pumps, electric vehicles and wind and solar power generation.
- Avoids or defers the cost and disruption of expanding our network of overhead lines, underground cables and substations.
- Reduces cost for electricity consumers.

The CLASS system provides a dashboard which is hosted within the network management system (NMS) that provides a graphical universal interface to allow the user to select pre-defined functions. This dashboard allows the user to select CLASS functionality to provide real-time and reactive power demand response. This dashboard displays the MW/MVAr demand response associated for the respective commands for all ENWL CLASS enabled primary substations and group totals. An algorithm within the network management system estimates the MW/MVAr response based on static load with a look up table to identify the parameters at a specific time of day. A similar dashboard also sits within the National Grid NMS to interact with the ENWL dashboard via Weblink which allows National Grid to activate CLASS functions when and when operating within commercial contract period.

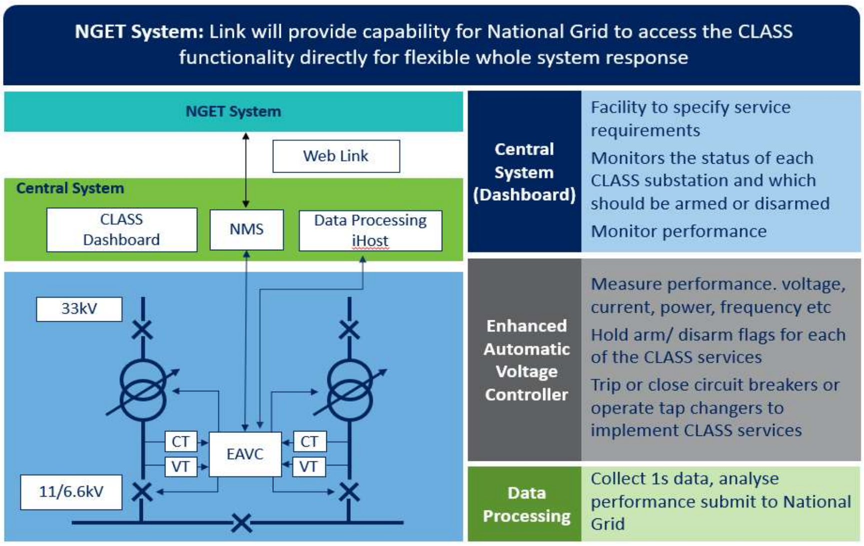

Figure 4: CLASS System Overview

4.4 Smart Street overview

Smart Street focuses on voltage optimisation on the LV network. At the heart of Smart Street is the optimisation software which uses real time measurement and configuration data to manage the voltage and power flows of the LV network. The Smart Street system uses optimisation software to autonomously manage the network through distribution transformers with On Load Tap Changers (OLTC) that adjust the voltage level on the LV network as and when required and also utilises LV Circuit Breakers (LVCBs) and LV switches to allow real-time network reconfiguration in line with optimisation software requirements. The Smart Street controllable switching devices, when integrated into the Network Management System (NMS), stabilise network voltages and prevent them from falling outside of statutory limits. This system will allow to optimise voltage levels so that both customers' appliances and the network run as efficiently as possible, using a technique known as Conservation Voltage Reduction (CVR).

CVR on the distribution network is defined as a reduction of energy consumption resulting from a voltage reduction along the feeder. As discussed above Smart Street optimises the voltage by utilising the OLTC transformers as these transformers are able to regulate the voltage along the feeder while maintaining statutory limits. This allows for peak load to be reduced, hence reducing annual energy consumption.

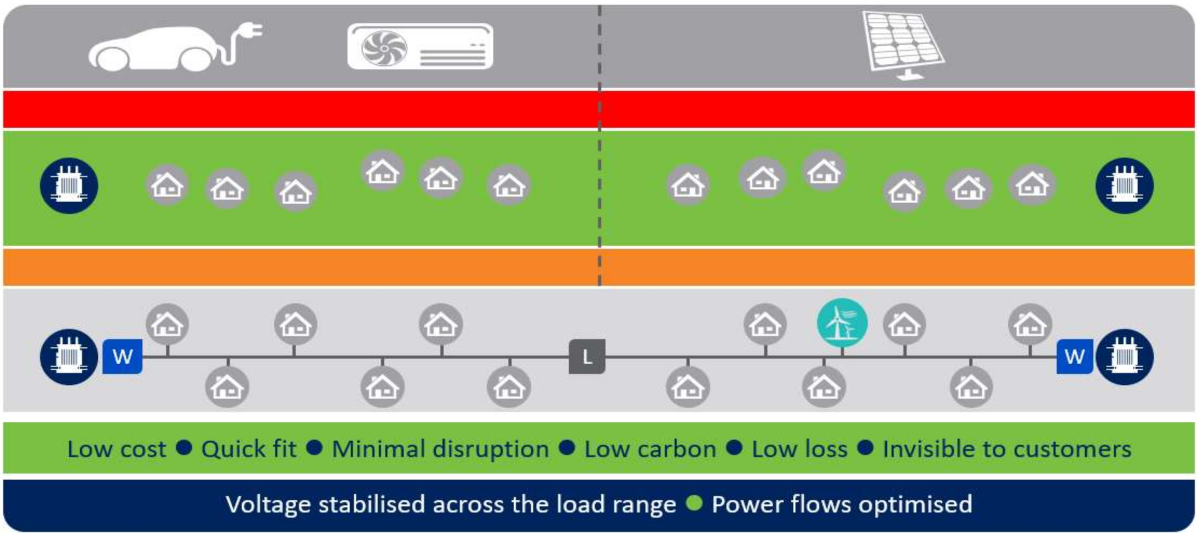

Figure 5: Smart Street System Overview

4.5 Use Cases 1 to 8

This section contains the eight Use Cases identified for the QUEST project and will be taken forward into the next phase of the project.

Use Case 1 Quest Network Efficiency

Use Case Name	QUEST Network Efficiency				
Use Case Number	UC 1	**Version**	1	**Status**	Final
Use Case Development Owner	ENWL				
Use Case Description	This use case describes the coordination between discrete systems at 33kV voltage levels to provide network efficiency. Customer Load Active System Services (CLASS) disabled, ANM (which enables Flexible Connections and Services) and Smart Street enabled provided by the QUEST Voltage Optimiser. The QUEST Voltage Optimiser executes in line with its "Operational Objective" to reduce network losses on the 33kV system.				
Primary users	DNO				
Secondary users	DNO				
Trigger	QUEST will automatically switch to network efficiency mode, minimising losses on the 33kV network, when all CLASS functions are in the disabled state (Outside commercial contracted periods). Both ANM and Smart Street are enabled. This is not a global optimum voltage optimisation. QUEST will determine the optimum 33kV voltage profile to minimise losses on the 33kV system. Smart Street will continue to operate in CVR mode.				
Preconditions	CLASS is disabled when no commercial agreements are in place. Smart Street is enabled. The ANM is managing various Distribution Energy Resources (DER) to control power flows at a number of constraint points on constraint management zones by issuing set points to DER at times to manage the constraint where				

	possible. The ANM has the capability to issue MW and MVAr set points. Cloud ANM Flexibility Service dispatch is operating. QUEST Voltage Optimiser is aware of all the applications that are enabled on the observed part of the network. QUEST Voltage Optimiser has visibility of voltages at the GSP, BSP and Primary substations and monitors actions taken by the systems. The Whitegate system (QUEST Trial Network) is a radial system, fed from a single voltage source and as such power flow swings caused by meshing is not considered under normal circumstances. Where system parallels are carried out for planned work, the control room takes action to prevent high flows through the system so this again would not be an issue.	
Post Conditions	Network is running in its most efficient mode. As per losses calculations in QUEST software.	
Main Success Scenario	**Steps**	**Actions**
	1	Optimal voltage profile across the 33kV network with ANM and smart street enabled, and CLASS disabled. QUEST to minimise systems losses to maximise financial benefits.
Conflict/Coordination Issue Path	1a	CLASS is enabled compromising network efficiency. This now is effectively a CLASS, Smart Street and ANM Use Case, refer Use Case number 5 for further details.
Possible Coordination Resolution Path	2	Refer to Use Case 5 for possible resolution.
Extensions	The initial user case is based on a radial type system. Network meshing/parallels should be evaluated to determine the effects of load flows and what measures need to be considered. Where parallels are required the control engineer will evaluate voltage	

	levels and take appropriate action prior to paralleling two separate sources. Ordinarily voltages are equalised at both sources by tapping the appropriate transformers and in some cases switching out a transformer. Voltage optimisation to include LV network. The benefit of Smart Street may reduce if the load mix changes and therefore impacting the voltage demand relationship. When Smart Street has limited benefits then the Voltage Optimization should include the LV.
Notes and Outstanding issues (if any)	**Assumption 1:** There are no faults on the network causing disruption to network efficiency. **Assumption 2:** Achieving network optimum efficiency is highest priority. **Assumption 3:** ANM will notify QUEST of any voltage violation within its Zones potentially caused by voltage optimisation. **Assumption 4**: QUEST can be switched in for individual zone. **Assumption 5:** Losses on the distribution network are measured as the difference between the units entering and those leaving the network. The measured losses fall into two categories: Technical and Commercial Losses. Commercial losses occur as a result of meter inaccuracies, theft, settlement errors, errors in estimates of un-metered supplies, etc. Technical losses are the units lost in transporting electricity across the network and are as a result of the physical nature of that network. The technical losses are divided into the fixed losses incurred through energisation of the network and variable losses that are incurred as a result of the power flow through the network.

Use Case 2 – Smart Street and Enhanced AVC Including CLASS

<table>
<tr><td>Use Case Name</td><td colspan="5">Smart Street and Enhanced AVC Including CLASS</td></tr>
<tr><td>Use Case Number</td><td>UC 2</td><td>Version</td><td>1</td><td>Statu s</td><td>Final</td></tr>
<tr><td>Use Case Development Owner</td><td colspan="5">ENWL</td></tr>
<tr><td>Use Case Description</td><td colspan="5">This use case describes the coordination between Enhanced AVC including CLASS and Smart Street functionalities provided by the QUEST algorithm (QUEST Voltage Optimiser). The QUEST Voltage Optimiser executes in line with its “Operational Objective”.</td></tr>
<tr><td>Primary users</td><td colspan="5">DNO / ESO</td></tr>
<tr><td>Secondary users</td><td colspan="5">None</td></tr>
<tr><td>Trigger</td><td colspan="5">QUEST is triggered when any of the CLASS functions are enabled, that will cause potential conflict between objectives or network issues due to coordination of actions with Smart Street.
These functions are either manual (or require an external signal to trigger) such as:
• Demand Reduction Function (DRF)
• Demand Boost Function (DBF)
• Tap stagger Function (TSF)
Or automatic, primed to act after a certain threshold is met, such as:
• Primary Frequency Response (PFR)
• Secondary Frequency Response (SFR)
• Load Limiting (LL)</td></tr>
<tr><td>Preconditions</td><td colspan="5">CLASS is enabled to execute several functions upon request from ESO or when providing commercial agreements. Where a commercial agreement is in place the DNO Control Room will enable the contracted services, which will only activate following a trigger from ESO or by an automatic network trigger such as frequency.
ANM will not considered part of the network.</td></tr>
</table>

	QUEST is not optimising the network for efficiency when CLASS is active. QUEST Voltage Optimiser is aware of all the applications that are enabled on the observed part of the network. QUEST Voltage Optimiser has visibility of voltages at the GSP, BSP and Primary substations and monitors actions taken by the systems.	
Post Conditions	Voltages on the HV and LV networks in the QUEST trial area are within the technical limits. CLASS maintains ability to provide the ESO services and DNO requirements on considered part of the network. Smart Street continuously optimizes voltages in the LV part of the network.	
Case 1: ESO Service -DRF		
Trigger	QUEST Voltage Optimiser assumes a potential conflict where CLASS's DRF activation would cause voltage violations in LV part of the network since the voltages in the LV part are already close to the low limit under the operation of Smart Street CVR.	
Main Success Scenario	**Steps**	**Actions**
	1	CLASS receives instruction from either ESO or DNO to execute DRF.
	2.	CLASS DRF function is activated on all the primaries where it was previously enabled by the CLASS scheduling mechanism.
No conflict	3a	CLASS achieves its objective without causing any low voltage violations that cannot be resolved by Smart Street.
Possible conflict	3b.	On several primaries where voltage reduction was performed CLASS does not achieve expected demand reduction due to Smart Street's reaction to performed voltage reduction.

		Voltage reduction causes low voltage violations in LV part of the network and Smart Street tries to resolve them by increasing the tap position on a distribution transformer and thus causing the demand to increase.
Possible conflict	3c.	CLASS achieves the expected demand reduction by applying the voltage reduction, but this action causes low voltage violations in LV part of the network which Smart Street cannot resolve by increasing the tap position on the distribution transformers since the voltage on the primary side of the distribution transformer is too low now.
Conflict Resolution	4	QUEST assumes Smart Street being enabled will cause issues with CLASS either achieving its objective or cause constraint issues. QUEST determines that Smart Street functionality needs to be put into a *"CLASS forecast and optimise mode (CFOM).* This mode will forecast when CLASS may activate and optimise the Smart Street set points. Securing the network against any issues whilst balancing all system objectives.
Case 2 – ESO Service -DBF		
Trigger	The QUEST Voltage Optimiser detects that CLASS's DBF function will: Make additional room for lowering the voltage values in LV part of the network which will additionally decrease the demand and possibly conflict the DBF objective.	
Main Success Scenario	**Steps**	**Actions**
Trigger	1	CLASS receives instruction from ESO to execute DBF.
No conflict	2a	CLASS alters the EAVC Relay set point to increase demand. Voltages on primary side of the 11kV/LV distribution transformers are increased which provides additional

		room for lowering the voltages by Smart Street operation, but all the transformers are already on the lowest tap position, so Smart Street does not provide any additional demand decrease and does not conflict the CLASS's DBF.
Conflict	2b	CLASS alters the EAVC Relay set point to increase demand. Voltages on primary side of the 11kV/LV distribution transformers are increased which provides additional room for lowering the voltages by Smart Street operation. Smart Street decreases or maintains the voltage values in LV part and thus decreases the demand which results in CLASS not achieving the expected demand boost.
Conflict Resolution	3b	QUEST assumes that CLASS's actions will cause Smart Street's reaction that will conflict achieving the CLASS's DBF objective. Hence QUEST determines that Smart Street functionality needs to be put into a *"CLASS forecast and optimise mode (CFOM)".* This Smart Street CFOM mode will be activated when CLASS DBF is enabled (at the NMS level) and will optimise the Smart Street set points. Securing the network against any issues whilst balancing all system objectives. On completion of the CLASS service, QUEST assumes that it is now safe to enable Smart Street functionality again.
Case 3 – ESO Service – TSF		
Triggers	Instruction from ESO	
Main Success Scenario	**Steps**	**Actions**
	1	CLASS receives instruction from ESO to execute TSF.

No conflict	2	CLASS activates the EAVC Relay to increase reactive power absorption. Smart Street tap operations reacting to the new voltage set point cause no issues. The actions cause no issues as planning margins are adequate to not reduce capacity The action does not alter voltage on the transformer's secondary causing Smart Street voltage issues.
Case 4 – ESO service – PFR/SFR		
Triggers		QUEST Voltage Optimiser assumes a potential conflict where low voltage tap activation would cause voltage violations in LV part of the network since the voltages in the LV part are already close to the low limit under the operation of Smart Street CVR.
Main Success Scenario	**Steps**	**Actions**
PFR	1	When PFR is enabled the EAVC Relay puts tap-stagger in place. Once the frequency threshold is exceeded PFR becomes automatically activated by the on-site EAVC relay. The 11/6.6kV CB of the Primary Transformer (33/11/6.6kV) which is on the higher tap position, out of the Primary Transformers is opened. The tapping does not normally take place during the frequency threshold excursion event.
No Conflict	2a	The CLASS PFR actions cause no issues as planning margins are adequate.
Conflict/Coordination Issue	2b	CLASS achieves voltage reduction, but this action causes low voltage violations in LV part of the network which Smart Street cannot resolve by increasing the tap position on the distribution transformers since the

		voltage on the primary side of the distribution transformer is too low now.
Possible Coordination Resolution Path	3	QUEST determines that Smart Street functionality needs to be put into a *"CLASS forecast and optimise mode (CFOM)".* This Smart Street CFOM mode will be activated when CLASS DBF is enabled (at the NMS level) and will optimize the Smart Street set points. Securing the network against any issues whilst balancing all system objectives.
SFR	1	The frequency threshold is exceeded and the EAVC Relay taps both transformers down.
No Conflict	2a	The CLASS SFR actions cause no issues as planning margins are adequate.
Conflict/Coordination Issue	2b	CLASS achieves voltage reduction, but this action causes low voltage violations in LV part of the network which Smart Street cannot resolve by increasing the tap position on the distribution transformers since the voltage on the primary side of the distribution transformer is too low now.
Possible Coordination Resolution Path	3	QUEST determines that Smart Street functionality needs to be put into a *"CLASS forecast and optimize mode". (CFOM)".* This Smart Street CFOM mode will be activated when CLASS DBF is enabled (at the NMS level) and will optimize the Smart Street set points. Securing the network against any issues whilst balancing all system objectives.
Extensions		None
Notes and Outstanding issues (if any)		**Assumption 1:** CLASS commitment should have priority over Smart Street. **Assumption 2:** Since DRF can be activated multiple times during the day, if Smart Street is enabled and is

	maintaining the voltages in LV part of the network, each DRF activation would cause excessive voltage violations in LV part of the network and this should be prevented through CLASS forecast and optimise mode (CFOM) optimising the control .

Use Case 3 Smart Street & ANM

<table>
<tr><td>Use Case Name</td><td colspan="5">Smart Street & ANM</td></tr>
<tr><td>Use Case Number</td><td>UC 3</td><td>Version</td><td>1</td><td>Status</td><td>Final</td></tr>
<tr><td>Use Case Development Owner</td><td colspan="5">ENWL</td></tr>
<tr><td>Use Case Description</td><td colspan="5">This use case describes the coordination between Smart Street and the systems providing Flexible Connection ANM functionalities (Central ANM NMS and Decentralised ANM) and Flexible Services ANM (Central ANM NMS and Cloud ANM) provided by the QUEST Voltage Optimiser. The QUEST Voltage Optimiser executes in line with its “Operational Objective”.</td></tr>
<tr><td>Primary users</td><td colspan="5">DNO</td></tr>
<tr><td>Secondary users</td><td colspan="5">ANM</td></tr>
<tr><td>Trigger</td><td colspan="5">The QUEST Voltage Optimiser assumes that Smart Street CVR on the LV network, in isolation or combined with ANM (Flexibility Service) dispatching, will result in flexible connection DER being constrained beyond their connection agreement curtailment index (CiD) due to demand/generation imbalance at ANM managed constraint points on the HV distribution network.</td></tr>
<tr><td>Preconditions</td><td colspan="5">Smart Street is enabled and is running in Conservation Voltage Reduction mode (CVR) Smart Street performs voltage reduction to the defined limits to provide demand reduction in LV parts of the network. LV voltages are close to the lower technical limit.

ANM is managing DER with flexible connection agreements to control power flows at thermal constraint points within its constraint management zone, issuing set points to DER when required. ANM has the capability to issue MW and MVAr set points.

The ANM is also providing Flexible Services when required.</td></tr>
</table>

	No CLASS functions are enabled on the considered part of the network. QUEST optimisation is not enabled. The QUEST Voltage Optimiser is aware of all the applications that are enabled on the observed part of the network. The QUEST Voltage Optimiser has visibility of voltages at the GSP, BSP and primary substations and monitors actions taken by the systems. Voltages in the network are within the statutory limits.	
Post Conditions	Voltages on the HV, and LV networks in the QUEST trial area are within the technical limits. Smart Street continues to optimize voltages in the LV part of the network. ANM continues to control power flows at thermal constraint points by managing the set points of DER with flexible connection agreements when required. The Flexible Services via ANM continues to be dispatched when needed without causing circuit limit violations on the network or curtailment of DER with flexible connection agreements.	
Main Success Scenario	**Steps**	**Actions**
	1	The QUEST Voltage Optimiser assumes that the level of Smart Street CVR demand reduction in isolation, or combined with a Flexible Service dispatching, may reduce available network capacity.
Conflict/Coordination Issue	2	The QUEST Voltage Optimiser does not intervene and both Smart Street and the ANM continue to operate independently of each other. This results in ENWL being penalised for exceeding the curtailment index at one or more generators.

Potential Resolution: Option A	3a.	The QUEST Voltage Optimiser monitors the duration of the detected conflict and records the start and end time for each generator pushed past their connection agreement curtailment index due to Smart Street CVR actions and or Flexible Service actions.
Potential Resolution: Option B	3b	QUEST Voltage Optimiser forecasts and optimises (based on its priority matrix) that it is less expensive to disable Smart Street CVR on some distribution transformers.
	4b.	The QUEST Voltage Optimiser reduces the level of Smart Street CVR allowing demand to increase (may need to disable CVR at one or more locations) affecting the ANM managed thermal constraint locations to avoid constraining one or more generator exports beyond their connection agreement curtailment index. The QUEST Voltage Optimiser monitors the duration of the Smart Street CVR restricted service and records the start and end time for each substation where CVR is reduced.
	5b.	The QUEST Voltage Optimiser forecasts and optimises when the Smart Street full CVR level can be restored without constraining any generators past their connection agreement curtailment index and restores the full CVR level, recording the start and end times of the intervention on each Smart Street location affected.
Potential Resolution Option C	2c.	QUEST Voltage Optimiser forecasts and optimises (based on its priority matrix) that it is less expensive to modify Flexible Service dispatching than disable Smart Street CVR on some distribution transformers to prevent the curtailment index being exceeded at one or more generators. QUEST Voltage Optimiser intervenes in Flexible Service dispatch via the ANM.
	3c	The QUEST Voltage Optimiser continues to modify the Flexible Service dispatch until no longer required or disabling Smart Street CVR becomes less expensive than

		modifying Flexible Service dispatching. The QUEST Voltage Optimiser records the start and end times of each intervention to each Smart Street location and similarly for each Flexible Service intervention.
Potential Resolution Option D	2d	This is an extension of Option B where the prevention of Flexible Connection curtailment more than the connection agreement curtailment index cannot be prevented at one or more generators through actions to disable Smart Street CVR. In this case the QUEST Voltage Optimiser will forecast and optimises (based on its priority matrix) if it is less expensive to intervene in Flexible Service dispatching to remove the Flexible Connection constraining.
	3d	The QUEST Voltage Optimiser continues to modify the Flexible Service dispatch until no longer required or allowing generator curtailment index to be exceeded becomes less expensive than modifying Flexible Service dispatching. The QUEST Voltage Optimiser will release Smart Street CVR and Flexible Service intervention when no longer required. The QUEST Voltage Optimiser records the start and end times of each intervention to each Smart Street location and similarly for each Flexible Service intervention.
Extensions	To enable options B-D an optimisation would need to be implemented to allow QUEST to understand the cost of when connection agreements (curtailment index) are breached and forecast when this may occur to alter its decision.	
Notes and Outstanding issues (if any)	**Assumption 1:** Smart Street actions are a higher priority than Flexible Connections (free to alter within Curtailment Index). **Option A:** Assumes no QUEST intervention, sticks to baseline priority list. Any contractual exceedances dealt with post analysis. QUEST extracts pertinent information to settle issues post event. **Option B-D:** Assumes QUEST intervention once contractual obligations result in ENWL penalties, implements interventions by varying priority list driven by exceedance of a curtailment index.	

	Assumption 2: The curtailment index measures the periods where the ANM DER set point instruction is not equal to full DER export capability. This would indicate the period where ANM intervention has occurred, not necessarily whether MW has been curtailed. When the CiD exceeds a certain (Contractual?) threshold, the cost of further curtailment would be applied, thus triggering an economic optimisation of each systems actions. This is a complex process that would require advanced online analytics and, therefore, considered an extension.

Use Case 4 – Enhanced AVC Including CLASS and ANM (Flexible service and connections

<table>
<tr><td>Use Case Name</td><td colspan="5">Enhanced AVC Including CLASS and ANM (Flexible service and connections).</td></tr>
<tr><td>Use Case Number</td><td>UC 4</td><td>Version</td><td>1</td><td>Status</td><td>Final</td></tr>
<tr><td>Use Case Development Owner</td><td colspan="5">ENWL</td></tr>
<tr><td>Use Case Description</td><td colspan="5">This use case describes the coordination between Enhanced AVC including CLASS and ANM (which enables Flexible Connections and Services) provided by the QUEST Voltage Optimiser. The QUEST Voltage Optimiser executes in line with its “Operational Objective”.</td></tr>
<tr><td>Primary users</td><td colspan="5">ESO</td></tr>
<tr><td>Secondary users</td><td colspan="5">DNO</td></tr>
<tr><td>Trigger</td><td colspan="5">QUEST is triggered when any of the CLASS functions, that will cause potential conflict between objectives or network issues due to coordination of actions with the ANM, are executed.
These functions are either manual or require an external signal to trigger, such as:
• Demand Reduction Function (DRF)
• Demand Boost Function (DBF
• Tap stagger Function (TSF)
Or automatic, primed to act after a certain threshold is met, such as:
• Primary Frequency Response (PFR)
• Secondary Frequency Response (SFR)
• Load Limiting (LL)</td></tr>
<tr><td>Preconditions</td><td colspan="5">CLASS is enabled to execute several functions upon request from ESO or commercial agreements. Where a commercial agreement is in place the DNO will enable the contracted services, which will only activate following a trigger from ESO or by an automatic network trigger such as frequency.</td></tr>
</table>

	The ANM is managing various Distribution Energy Resources (DER) to control power flows at a number of constraint points on constraint management zones by issuing set points to DER at times to manage the constraint where possible. The ANM has the capability to issue MW and MVAr set point. Smart Street is not operating in CVR mode. QUEST is not optimising the network for efficiency beyond the enabled systems. QUEST Voltage Optimiser is aware of all the applications that are enabled on the observed part of the network. Quest Voltage Optimiser has visibility of voltages at the GSP, BSP and Primary substations and monitors actions taken by the systems.	
Post Conditions	Voltages on the HV and LV networks in the QUEST trial area are within the technical limits. CLASS continuously enables ESO services and ANM continues to control power flows at constraint points by managing the set points of DER when required.	
Main Success Scenario	**Steps**	**Actions**
Trigger-DRF	1	CLASS receives instruction from either ESO or DNO to execute DRF.
No Conflict	2a	CLASS activates the EAVC Relay to reduce demand. The result causes no thermal violation in the constraint management zone. The ANM achieves full-service provision.
Conflict/Coordination Issue Path	2b	CLASS activates the EAVC Relay to reduce demand. The action causes a reduction in local demand, increasing export at a thermal constraint, leading to a violation in the constraint management zone.

		The ANM alters DER set points to solve thermal constraint issue, this can cause a flexible connection to exceed its CiD. A DER providing a flexible service, associated with the constraint is forced to reduce dispatch, resulting in partial service provision.
Possible Coordination Resolution Path	2c	QUEST presumes CLASS actions may cause a temporary constraint violation as the system transitions from one steady state to the next if uncoordinated. QUEST instructs ANM to move into *“CLASS forecast and Optimise Mode (CFOM).* This mode will forecast when CLASS may become active and optimise the ANM (connections and services) set points and dispatch schedules as appropriate (Cloud ANM). Securing the network against any issues whilst balancing all system objectives and constraints e.g. not exceeding curtailment index. CLASS activates the EAVC Relay to reduce demand. QUEST records pertinent parameters to audit the conflict/coordination resolution action on its impact to other systems/services as a post analysis. On completion of the CLASS service, QUEST instructs ANM to return to its original operational mode.
Trigger-DBF	1	CLASS receives instruction from ESO to execute DBF.
No Conflict	2a	CLASS activates the EAVC Relay to increase demand. The action does not cause capacity at a constraint location to be released. The ANM achieves full-service provision.
Conflict/Coordination Issue Path	2b	CLASS activates the EAVC Relay to increase demand. The action does cause capacity at a constraint location to be released.

		The ANM alters DER set points to release any constrained DER up to the released capacity, possibly reducing the impact of CLASS actions.
Possible Coordination Resolution Path	2c	QUEST presumes CLASS actions may cause a temporary constraint violation as the system transitions from one steady state to the next if uncoordinated. QUEST instructs ANM to move into *"CLASS forecast and Optimise Mode (CFOM).* This mode will forecast when CLASS may become active and optimise the ANM (connections and services) set points and dispatch schedules as appropriate (Cloud ANM). Securing the network against any issues whilst balancing all system objectives and constraints e.g. not exceeding curtailment index. CLASS activates the EAVC Relay to increase demand. QUEST records pertinent parameters to audit the conflict/coordination resolution action on its impact to other systems/services as a post analysis. On completion of the CLASS service, QUEST instructs ANM to return to its original operational mode.
Trigger-TSF	1	CLASS receives instruction from ESO to execute TSF.
No Conflict	2a	CLASS activates the EAVC Relay to increase reactive power absorption. The action does not cause constraint violation in the constraint management zone. The ANM achieves full-service provision.
PFR	1	When PFR is enabled the EAVC Relay puts tap-stagger in place. Once the frequency threshold is exceeded PFR becomes automatically activated by the EAVC relay. The 11/6.6kV CB of the Primary Transformer (33/11/6.6kV) which is on the higher tap position, out of the Primary

		Transformers is opened. The tapping does not normally take place during the frequency threshold excursion event.
No Conflict	2a	This action does not cause a thermal constraint violation in the constraint management zone.
Conflict/Coordination Issue Path	2b	The EAVC Relay instructs a primary transformer pair to open one CB. The action does cause a thermal constraint violation in the constraint management zone. The ANM alters generation set points to solve thermal constraint issue.
Possible Coordination Resolution Path	2c	QUEST assumes CLASS actions will cause a temporary constraint violation if uncoordinated. QUEST instructs ANM to move into *"CLASS forecast and Optimise Mode (CFOM).* This mode will forecast when CLASS may become active and optimise the ANM (connections and services) set points and dispatch schedules as appropriate (Cloud ANM). Securing the network against any issues whilst balancing all system objectives and constraints e.g. not exceeding curtailment index. CLASS PFR Activated. On completion of the CLASS service, the EAVC Relay reinstates the CB moving to post event state. QUEST sets the ANM objective back to normal.
SFR	1	The frequency threshold, monitored by CLASS, is exceeded.
No Conflict	2a	The EAVC Relay instructs a primary transformer pair to tap down. The action does not cause a thermal constraint violation in the constraint management zone.
Conflict/Coordination Issue Path	2b	The EAVC Relay instructs a primary transformer pair to tap down.

		The action does cause a thermal constraint violation in the constraint management zone. The ANM alters generation set points to solve thermal constraint issue.
Possible Coordination Resolution Path	2c	QUEST presumes CLASS actions will cause a temporary constraint violation if uncoordinated. QUEST instructs ANM to move into *"CLASS forecast and Optimise Mode (CFOM).* This mode will forecast when CLASS may become active and optimise the ANM (connections and services) set points and dispatch schedules as appropriate (Cloud ANM). Securing the network against any issues whilst balancing all system objectives and constraints e.g. not exceeding curtailment index. The EAVC Relay instructs both primary transformer pairs to tap down. On completion of the CLASS service QUEST sets the ANM objective back to normal.
Extensions	The forecast and optimise mode could be: • A simple rule-based approach assumes (forecasting) the worst-case condition and prioritising (optimising) certain system objectives ahead of others. • A complex forecast of network state to predict when abnormal conditions may occur and implement a multi-objective optimisation that blends discrete system objectives to achieve a global optimum.	
Notes and Outstanding issues (if any)	**Assumption 1:** CLASS will not induce a voltage constraint due to its actions. **Assumption 2:** Achieving CLASS objectives has the highest priority and QUEST will forecast and optimise systems in line with this. **Assumption 3**: ENWL want to reduce any constraint exceedances during the transition from one network steady state to another. **Assumption 4:** Tap Stagger is implemented on transformers that are loaded appropriately to allow increase in total MVA not to exceed equipment rating.	

Use Case 5 – Smart Street, Enhanced AVC Including CLASS and ANM

Use Case Name	Smart Street, Enhanced AVC Including CLASS and ANM				
Use Case Number	UC 5	**Version**	1	**Status**	Final
Use Case Development Owner	ENWL				
Use Case Description	This use case identifies the conflict and coordination issues between Enhanced AVC including CLASS, Smart Street, and ANM functionalities (which enables Flexible Connections and Flexible Services). It also suggests possible resolutions provided by the QUEST Voltage Optimiser. The QUEST Voltage Optimiser executes in line with its "Operational Objective".				
Primary users	ESO, DNO				
Secondary users	DNO				
Trigger	QUEST is triggered when any of the CLASS functions, that will cause potential conflict between objectives or network issues due to coordination of actions with Smart Street and the ANM, are executed. These functions are either manual or require an external signal to trigger, such as: • Demand Reduction Function (DRF) • Demand Boost Function (DBF • Tap stagger Function (TSF) Or automatic, primed to act after a certain threshold is met, such as: • Primary Frequency Response (PFR) • Secondary Frequency Response (SFR) • Load limiting (LL)				
Preconditions	CLASS is enabled to execute a number of functions upon request from ESO or commercial agreements. Where a commercial agreement is in place the DNO will enable the contracted services,				

	which will only activate following a trigger from ESO or by an automatic network trigger such as frequency. Smart Street performs voltage reduction to the defined limits to provide demand reduction in LV parts of the network. LV voltages are close to the lower technical limit. The ANM is managing various Distribution Energy Resources (DER) to control power flows at a number of constraint points on constraint management zones by issuing set points to DER at times to manage the constraint where possible. The ANM has the capability to issue MW and MVAr set points. Cloud ANM Flexible Services dispatching are operating according to a day ahead dispatch schedule. QUEST Voltage Optimiser is aware of all the applications that are enabled on the observed part of the network. QUEST Voltage Optimiser has visibility of voltages at the GSP, BSP and Primary substations and monitors actions taken by the systems.	
Post Conditions	Voltages on the, HV and LV networks in the QUEST trial area are within the technical limits. CLASS continuously enables ESO services and, Smart Street enables CVR and ANM continues to control power flows at constraint points by managing the set points of DER when required. Cloud ANM Flexibility Service dispatch continues with a revised schedule where required.	
Main Success Scenario	**Steps**	**Actions**
DRF	1	CLASS receives instruction from either ESO or DNO to execute DRF.
No Conflict	2a	CLASS activates the EAVC Relay to reduce demand. The result causes no thermal violation in the constraint management zone. ANM achieves full-service provision.

		Smart Street tap operations reacting to the new voltage set point cause no issues.
Conflict/Coordination Issue Path	2b	CLASS activates the EAVC Relay to reduce demand. The action causes a reduction in local demand, increasing export at a thermal constraint, leading to a violation in the constraint management zone. The ANM alters DER set points to solve thermal constraint issue. DER providing a flexible service, associated with the constraint is forced to reduce dispatch, resulting in partial service provision. Smart Street tap operations, reacting to the new voltage, may not resolve the LV violation.
Possible Coordination Resolution Path	3	QUEST presumes CLASS actions may cause a temporary constraint violation if uncoordinated with ANM and continuous if uncoordinated with Smart Street. QUEST instructs ANM to move into *"CLASS forecast and Optimise Mode (CFOM).* This mode will forecast when CLASS may become active and optimise the ANM (connections and services) set points and dispatch schedules as appropriate (Cloud ANM). Securing the network against any issues whilst balancing all system objectives and constraints e.g. not exceeding curtailment index. QUEST determines that Smart Street functionality needs to be put into a *"CLASS forecast and optimise mode (CFOM).* This mode will forecast when CLASS may activate and optimise the Smart Street set points. Securing the network against any issues whilst balancing all system objectives. CLASS activates the EAVC Relay to reduce demand.

		QUEST records pertinent parameters to audit the conflict/coordination resolution action on its impact to other systems/services as a post analysis. On completion of CLASS service, QUEST informs ANM and Smart Street to move back into normal operation modes.
DBF	1	CLASS receives instruction from ESO to execute DBF.
No Conflict	2a	CLASS activates the EAVC Relay to increase demand. The action does not cause capacity at a constraint location to be released. Smart Street tap operations reacting to the new voltage set point cause no issues. The ANM achieves full-service provision.
Conflict/Coordination Issue Path	2b	CLASS activates the EAVC Relay to increase demand. The action causes capacity at a constraint location to be released. The ANM alters DER set points to release generation up to the released capacity, reducing the impact of CLASS actions. Smart Street tap operations, reacting to the new voltage state, decreasing demand within their area and the wider area, reducing the impact of CLASS actions. The ANM arranges a service associated with the release of capacity e.g. (battery export)
Possible Coordination Resolution Path	2c	QUEST presumes ANM, Smart Street actions will interfere with CLASS objective if uncoordinated. QUEST instructs ANM to move into *"CLASS forecast and Optimise Mode (CFOM).* This mode will forecast when CLASS may become active and optimise the ANM (connections and services) set points and dispatch schedules as appropriate (Cloud ANM). Securing the

		network against any issues whilst balancing all system objectives and constraints e.g. not exceeding curtailment index. QUEST determines that Smart Street functionality needs to be put into a *"CLASS forecast and optimise mode (CFOM).* This mode will forecast when CLASS may activate and optimise the Smart Street set points. Securing the network against any issues whilst balancing all system objectives. CLASS activates the EAVC Relay to increase demand. QUEST records pertinent parameters to audit the conflict/coordination resolution action on its impact to other systems/services as a post analysis. On completion of the CLASS service QUEST informs ANM and Smart Street to resume its normal operation mode.
TSF	1	CLASS receives instruction from ESO to execute TSF.
	2a	CLASS activates the EAVC Relay to increase reactive power absorption. The action does not cause constraint violation in the constraint management zone. The ANM achieves full-service provision. Smart Street tap operations, reacting to the new voltage set point, cause no issues.
PFR	1	When PFR is enabled the EAVC Relay puts tap-stagger in place. Once the frequency threshold is exceeded PFR becomes automatically activated by the on-site EAVC relay. The 11/6.6kV CB of the Primary Transformer (33/11/6.6kV) which is on the higher tap position, out of the Primary Transformers is opened. The tapping does not normally take place during the frequency threshold excursion event.

No Conflict	2a	The action does not cause a thermal constraint violation in the constraint management zone.
Conflict/Coordination Issue Path	2b	PFR activation causes a thermal constraint violation in the constraint management zone. The ANM alters generation set points to solve thermal constraint issue. Smart Street tap operations, reacting to the new voltage, causes low voltage issue it cannot resolve.
Possible Coordination Resolution Path	2c	QUEST presumes CLASS actions will cause a temporary constraint violation if uncoordinated. QUEST instructs ANM to move into *"CLASS forecast and Optimise Mode".* This mode will forecast when CLASS may become active and optimise the ANM (connections and services) set points and dispatch schedules as appropriate (Cloud ANM). Securing the network against any issues whilst balancing all system objectives CLASS instructs a primary transformer pair to open one CB, and the other to tap down. QUEST determines that Smart Street functionality needs to be put into a *"CLASS forecast and optimise mode".* This mode will forecast when CLASS may activate and optimise the Smart Street set points. Securing the network against any issues whilst balancing all system objectives. On completion of the CLASS service, the EAVC Relay reinstates the CB moving to post event state. QUEST sets the Smart Street and ANM objective back to normal.
SFR	1	The frequency threshold, monitored by CLASS, is exceeded.
No Conflict	2a	The EAVC Relay instructs a primary transformer pair to tap down.

		The action does not cause a thermal constraint violation in the constraint management zone.
Conflict/Coordination Issue Path	2b	The EAVC Relay instructs a primary transformer pair to tap down. The action does cause a thermal constraint violation in the constraint management zone. The ANM alters generation set points to solve thermal constraint issue. Smart Street tap operations, reacting to the new voltage, causes low voltage issue it cannot resolve.
Possible Coordination Resolution Path	2c	QUEST presumes CLASS actions will cause a temporary constraint violation if uncoordinated. QUEST instructs ANM to move into *"CLASS forecast and Optimise Mode (CFOM).* This mode will forecast when CLASS may become active and optimise the ANM (connections and services) set points and dispatch schedules as appropriate (Cloud ANM). Securing the network against any issues whilst balancing all system objectives QUEST determines that Smart Street functionality needs to be put into a *"CLASS forecast and optimise mode (CFOM)* This mode will forecast when CLASS may activate and optimise the Smart Street set points. Securing the network against any issues whilst balancing all system objectives. The EAVC Relay instructs both primary transformers to tap down. CLASS SRF deactivated, transformers tap back up. QUEST sets the Smart Street and ANM objective back to normal.
Extensions	The forecast and optimise mode could be:	

	• A simple rule-based approach, presuming (forecasting) the worst-case condition and prioritising (optimising) certain system objectives ahead of others. • A complex forecast of network state to predict when abnormal conditions may occur and implement a multi-objective optimisation that blends discrete system objectives to achieve a global optimum.
Notes and Outstanding issues (if any)	**Assumption 1:** CLASS will not induce a voltage constraint due to its actions. **Assumption 2:** Achieving CLASS objectives has the highest priority and QUEST will forecast and optimise systems in line with this. **Assumption 3:** ENWL want QUEST to minimise or mitigate constraint exceedance during network state transition. **Assumption 4:** Tap Stagger is implemented on transformers that are loaded appropriately to allow increase in total MVA not to exceed equipment rating.

Use Case 6 Smart Street, Enhanced AVC Including CLASS, ANM & LFDD

Use Case Name	Smart Street, Enhanced AVC Including CLASS, ANM & LFDD				
Use Case Number	UC 6	**Version**	1	**Status**	Final
Use Case Development Owner	ENWL				
Use Case Description	This use case describes the coordination between Low Frequency Demand Disconnection (LFDD) activation from ESO and Enhanced AVC including CLASS, Smart Street and ANM (which enables Flexible Connections and Services) provided by the QUEST Voltage Optimiser. The QUEST Voltage Optimiser executes in line with its "Operational Objective".				
Primary users	ESO				
Secondary users	DNO				
Trigger	QUEST is triggered when it sees LFDD alarms come in from the DNO SCADA system.				
Preconditions	Smart Street, CLASS, ANM enabled, all systems running in normal operating conditions. CLASS is enabled to execute a number of functions upon request from ESO or commercial agreements. Where a commercial agreement is in place the DNO will enable the contracted services, which will only activate following a trigger from ESO or by an automatic network trigger such as frequency. QUEST is not in "efficiency mode" QUEST Voltage Optimiser is aware of all the applications that are enabled on the observed part of the network. Quest Voltage Optimiser has visibility of voltages at the GSP, BSP and Primary substations and monitors actions taken by the systems.				
Post Conditions	LFDD has acted as expected (demand disconnected and not yet restored), CLASS remains enabled, Smart Street and ANM go into LFDD mode.				

		CLASS continuously enables ESO services and ANM continues to control power flows at constraint points by managing the set points of DER when required while in LFDD mode. Cloud ANM Flexibility Service dispatch operates within LFDD mode. QUEST to maintain system voltages within statutory limits where possible. QUEST is not in" efficiency mode".
Main Success Scenario	**Steps**	**Actions**
LFDD	1	LFDD relays respond to system change, and begin to open CB's at BSP's
	2	QUEST freezes its voltage optimisation at BSP's
	3	QUEST disables signal to Smart Street (Maintains last input from system command). Smart street is disabled, (maintains last instructed setpoint). Suggestion: QUEST determines that Smart Street functionality needs to be put into a "LFDD forecast and optimise mode". This mode will forecast when LFDD may activate and optimise the Smart Street set points. Securing the network against any issues whilst balancing all system objectives.
	4	QUEST puts ANM into LFDD mode. (Manages thermal constraints as normal but does not release constrained capacity.) Cloud ANM Flexibility Service dispatch put into LFDD mode e.g. may halt dispatching of flexible services.
	5	QUEST makes no change to CLASS status.
	6	Instruction from ESO to return systems to precondition state.
Conflict/Coordination Issue Path		There Is no envisioned conflict.

Extensions	None
Notes and Outstanding issues (if any)	**Assumption 1:** LFDD instruction is priority over all system operating constraints. **Assumption 2:** ENWL are looking to modify (via sperate project) the way LFDD is implemented via the CLASS relays. This may affect the current LFDD CLASS interaction.

Use Case 7 Smart Street, Enhanced AVC Including CLASS, ANM & OC6

Use Case Name	Smart Street, Enhanced AVC Including CLASS, ANM & OC6 (OC6.5 demand control disconnection as per grid code)				
Use Case Number	UC 7	**Version**	1	**Status**	Final
Use Case Development Owner	ENWL				
Use Case Description	This use case describes the coordination between OC6 activation from ESO and Enhanced AVC including CLASS, Smart Street, and ANM (which enables Flexible Connections and Services) provided by the QUEST Voltage Optimiser. The QUEST Voltage Optimiser executes in line with its "Operational Objective". **Operating Code No.6 (OC6) =** The Grid Code for obligations on Network Operators to reduce demand on instruction from the ESO when having a risk of insufficient generation to meet total System demand. This excludes LFDD operating code No.6.6.				
Primary users	ESO				
Secondary users	DNO				
Trigger	Upon instruction from ESO to reduce demand in the event of insufficient Active Power generation being available to meet Demand.				
Preconditions	Smart Street, CLASS, ANM enabled, all systems running in normal operating conditions. CLASS is enabled to execute a number of functions upon request from ESO or commercial agreements. Where a commercial agreement is in place the DNO will enable the contracted services which will only activate following a trigger from ESO. QUEST is not in "efficiency mode" QUEST Voltage Optimiser is aware of all the applications that are enabled on the observed part of the network. Quest Voltage				

	Optimiser has visibility of voltages at the GSP, BSP and Primary substations and monitors actions taken by the systems	
Post Conditions	OC6 has implemented as requested (demand reduction / disconnected and not yet restored), CLASS remains enabled, Smart Street and ANM go into OC6 mode. CLASS continuously enables ESO services and ANM continues to control power flows at constraint points by managing the set points of DER when required while in OC6 mode. Cloud ANM Flexibility Service dispatch operates within OC6 mode. QUEST to maintain system voltages within statutory limits where possible. QUEST is not in “efficiency mode”.	
Main Success Scenario	**Steps**	**Actions**
OC6 Instruction	1	DNO Control Room follows due process according to OC6.5 / 6.7 requirement.
	2	DNO Control Room applies voltage reduction & demand disconnection and causes the following conflicts.
Conflict/Coordination Issue Path	1a	The result causes thermal constraint violation in the constraint management zone.
	1b	Smart street will potentially counter act demand reduction where voltage reduction applied.
	1c	QUEST attempts to optimise network impacting demand reduction capability.
Possible Coordination Resolution Path	2	DNO Control Room puts QUEST into OC6 mode. Which will automatically follow steps 2A to 2C below.
	2a	QUEST Voltage Optimiser freezes its voltage optimisation at BSP’s

	2b	QUEST Voltage Optimiser sends global freeze taps signal to smart street transformers.
	2c	QUEST Voltage Optimiser puts ANM into OC6 mode. (Manages thermal constraints as normal but does not release constrained capacity. Cloud ANM Flexibility Service dispatch put into OC6 mode e.g. may halt dispatching of flexible services.)
	3	DNO Control Room follows due process according to OC6.5 / 6.7 requirement.
	4	QUEST Voltage Optimiser makes no change to CLASS status.
	5	Confirmation from ESO to restore load as instructed.
	6	DNO Control Room restores system to normal operation as per preconditions stated above. (Normal operating condition).
	7	DNO Control Room to take QUEST out of OC6 mode.
Extensions	None	
Notes and Outstanding issues (if any)	**Assumption 1:** OC6 instruction is priority over all system operating constraints.	

Use Case 8 Smart Street, Enhanced AVC Including CLASS, ANM & Reactive Power Response

Use Case Name	Smart Street, Enhanced AVC Including CLASS, ANM & Reactive Power Response				
Use Case Number	UC8	**Version**	1	**Status**	Final
Use Case Development Owner	ENWL				
Use Case Description	This use case describes the coordination between reactive power response to ESO, Enhanced AVC including CLASS, Smart Street and ANM (which enables Flexible Connections and Services) provided by the QUEST Voltage Optimiser. The QUEST Voltage Optimiser executes in line with its “Operational Objective”. Reactive power response is a contractual agreement to provide ESO with reactive power management.				
Primary users	ESO				
Secondary users	DNO				
Trigger	Activation of Reactive Power Response from ESO.				
Preconditions	Smart Street, CLASS (all functions except PFR), ANM enabled systems are all running in normal operating conditions. CLASS is enabled to execute a number of functions upon request from ESO or commercial agreements. Where a commercial agreement is in place the DNO will enable the contracted services, which will only activate following a trigger from ESO or by an automatic network trigger such as frequency. QUEST Voltage Optimiser is aware of all the applications that are enabled on the observed part of the network. Quest Voltage Optimiser has visibility of voltages at the GSP, BSP and Primary substations and monitors. QUEST is not in “efficiency mode” QUEST enables BSP TSF mode, which reduces 33kV setpoint to maximise tap stagger capability at CLASS sites.				

Post Conditions	Reactive power response has been provided CLASS remains enabled, Smart Street, ANM are in precondition mode. Voltages on the HV, and LV networks in the QUEST trial area are within the technical limits. CLASS continuously enables ESO services and ANM continues to control power flows at constraint points by managing the set points of DER when required. QUEST to maintain system voltages within statutory limits where possible. Cloud ANM Flexibility Service dispatch continues with a revised schedule where required. QUEST is not in" efficiency mode"	
Main Success Scenario	**Steps**	**Actions**
Reactive Power Response	1	CLASS Dashboard receives instruction from ESO to execute TSF.
	2	CLASS Dashboard activates EAVC Relay to increase reactive power absorption. The result causes no thermal violation in the constraint management zone.
	3	QUEST does not affect Smart Street or ANM operability.
	4	Once reactive power response has been deactivated, system returns to normal precondition state.
Conflict/Coordination Issue Path		None
Extensions	**1** QUEST cannot find enough capacity available to absorb reactive power. This would occur if all available sites have already activated tap stagger. Adding Tap Stagger at 132/33kV substations will add a greater reactive power response. **2** If a primary transformer reaches the bottom tap, its supplying 132/33kV grid transformers could have their target voltage adjusted downwards to create more "tap room" (and even vice versa).	
Notes and Outstanding issues (if any)	**Assumption 1.** Reactive power absorption can be implemented at 132/33 kV substations without conflicting with CLASS, Smart Street, or flexible connections or services. It may be limited by	

	reaching the end of the tap range, by restrictions on the amount of circulating current or by the potential voltage step change if one of the transformers trips out. **Assumption 2**. There will be no noticeable effect on customer voltage levels during reactive power response activation. **Assumption 3.** Fail safe mode to be considered during loss of comms within SuperTAPP SG relays already installed in primary substations during tap stagger mode.

4.6 QUEST Use Case Matrix

This matrix represents an overview of the Use Cases outlined within this report, and summarises different applications of each Use Case, including a short description of any conflict / potential conflict within that case.

	Use Case	Trigger	Systems for QUEST to Co-ordinate				General Comments regarding protentional system conflicts/resolution
			ESO	Enhanced AVC Including CLASS	Smart Street	ANM	
1	**QUEST running in network efficiency mode**	**N/A**	N/A	DISABLED	ENABLED	ENABLED/Possible or acceptable conflict!	QUEST operating in network efficiency mode may impact ANM if volts too high. Raising system voltages increases capacity for generation.
1	**QUEST running in network efficiency mode**	**N/A**	N/A	ENABLED (DRF/SFR/PFR/DBF/TS)	Alternative mode due to CLASS/SS conflict	Alternative mode due to CLASS/ANM conflict	QUEST will need to set voltages at a level whereby Tap range is available for required CLASS function. Consider modifications to CLASS to provide tap availability to QUEST to allow optimal settings. When CLASS DRF/DBF is enabled, new Smart Street set points would be required to prevent Smart Street from reversing CLASS demand reduction/increase. Potential for ANM to signal DER for certain CLASS functions. QUEST will need to send appropriate signal to ANM, when any Class Function (except TS) is enabled, to mitigate conflict.
1	**QUEST running in network efficiency mode**	**N/A**	N/A	ACTIVE (DRF/SFR/PFR/DBF/TS)	Alternative mode due to CLASS/SS conflict	Alternative mode due to CLASS/ANM conflict	QUEST will need to set voltages at a level whereby Tap range is available for required CLASS function. Consider modifications to CLASS to provide tap availability to Quest to allow optimal settings. When CLASS DRF/DBF is enabled, new Smart Street set points would be required to prevent Smart Street from reversing CLASS demand reduction/increase. Potential for ANM to signal DER for certain CLASS functions. QUEST will need to send appropriate signal to ANM, when any Class Function (except TS) is enabled, to mitigate conflict.
2	**Smart Street and CLASS**	**CLASS function ENABLED/ACTIVE**	N/A	DISABLED	ENABLED	N/A	QUEST operating in network efficiency mode.

2	**Smart Street and CLASS**	**CLASS function ENABLED/ACTIVE**	N/A	ENABLED (DRF/SFR/PFR/DBF/TS)	Alternative mode due to CLASS/SS conflict	N/A	Conflict in the event that CLASS functions activated. Potential for CLASS DR to be cancelled out by Smart Street. QUEST will need to send appropriate signal to Smart Street, when any Class Function (except TS) is enabled, to mitigate conflict.
2	**Smart Street and CLASS**	**CLASS function ENABLED/ACTIVE**	N/A	ACTIVE (DRF/SFR/PFR/DBF/TS)	Alternative mode due to CLASS/SS conflict	N/A	Conflict in the event that CLASS functions activated. Potential for CLASS DR to be cancelled out by Smart Street. QUEST will need to send appropriate signal to Smart Street, when any Class Function (except TS) is enabled, to mitigate conflict.
3	**Smart Street and ANM**	**ANM or Smart Street active**	N/A	N/A	ENABLED	ENABLED	ANM load/generation planned using P2/6 and therefore ANM should not cause issues with SS or vice versa.
4	**CLASS and ANM**	**CLASS function ENABLED/ACTIVE**	N/A	DISABLED	N/A	ENABLED/Possible or acceptable conflict!	QUEST operating in network efficiency mode may impact ANM if volts too high. Raising system voltages increases capacity for generation.
4	**CLASS and ANM**	**CLASS function ENABLED/ACTIVE**	N/A	ENABLED (DRF/SFR/PFR/DBF/TS)	N/A	Alternative mode due to CLASS/ANM conflict	Conflict in the event that CLASS functions activated. Potential for ANM to signal DER for certain CLASS functions. QUEST will need to send appropriate signal to ANM, when any Class Function (except TS) is enabled, to mitigate conflict.
4	**CLASS and ANM**	**CLASS function ENABLED/ACTIVE**	N/A	ACTIVE (DRF/SFR/PFR/DBF/TS)	N/A	Alternative mode due to CLASS/ANM conflict	Conflict in the event that CLASS functions activated. Potential for ANM to signal DER for certain CLASS functions. QUEST will need to send appropriate signal to ANM, when any Class Function (except TS) is enabled, to mitigate conflict.
5	**CLASS, Smart Street and ANM**	**CLASS function ENABLED/ACTIVE**	N/A	DISABLED	ENABLED	ENABLED/Possible or acceptable conflict!	QUEST operating in network efficiency mode may impact ANM if volts too high. Raising system voltages increases capacity for generation.

5	**CLASS, Smart Street and ANM**	**CLASS function ENABLED/ACTIVE**	N/A	ENABLED (DRF/SFR/PFR/DBF/TS)	ENABLED but 66peration in alternative mode due to CLASS/SS conflict	ENABLED but operating in alternative mode due to CLASS/NM conflict	QUEST will need to set voltages as a level whereby Tap range is available for required CLASS function. Consider modifications to CLASS to provide tap availability to Quest to allow optimal settings. When CLASS DRF/DBF enables new Smart Street set points would be required to prevent Smart Street from reducing CLASS demand reduction/Increase. Potential for ANM to signal DER for certain CLASS functions. QUEST will need to send appropriate signal to ANM, when any Class Function (except TS) is enabled, to mitigate conflict.
5	**CLASS, Smart Street and ANM**	**CLASS function ENABLED/ACTIVE**	N/A	ACTIVE (DRF/SFR/PFR/DBF/TS)	ENABLED but 66peration in alternative mode due to CLASS/SS conflict	ENABLED but operating in alternative mode due to CLASS/ANM conflict	QUEST will need to set voltages as a level whereby Tap range is available for required CLASS function. Consider modifications to CLASS to provide tap availability to Quest to allow optimal settings. When CLASS DRF/DBF enables new Smart Street set points would be required to prevent Smart Street from reducing CLASS demand reduction/Increase. Potential for ANM to signal DER for certain CLASS functions. QUEST will need to send appropriate signal to ANM, when any Class Function (except TS) is enabled, to mitigate conflict.
6	**LFDD, CLASS, Smart St and ANM**	**LFDD**	LFDD	ENABLED (DRF/SFR/PFR/DBF/TS)	ENABLED but 66peration in alternative mode due to LFDD/SS conflict	ENABLED but operating in alternative mode due to LFDD/ANM conflict	LFDD conflict with Smart street and ANM. Both Smart Street and ANM to operate in alternative mode to maintain system stability for NG. Following LFDD operation DNO to maintain system demand so not to cause any change in system state (balance) that may have a negative impact on transmission system.
6	**LFDD, CLASS, Smart St and ANM**	**LFDD**	LFDD	ACTIVE (DRF/SFR/PFR/DBF/TS)	ENABLED but 66peration in alternative mode due to LFDD/S	ENABLED but operating in alternative mode due to LFDD/ANM conflict	LFDD conflict with Smart street and ANM. Both Smart Street and ANM to operate in alternative mode to maintain system stability for NG. Following LFDD operation DNO to maintain system demand so not to cause any change in system state (balance) that may have a negative impact on transmission system.

					S conflict		
7	**OC6, CLASS, Smart St and ANM**	**OC6**	OC 6	ENABLED (DRF/SFR/PFR/DBF/TS)	Alternative mode due to OC6/SS conflict	Alternative mode due to OC6/ANM conflict	OC 6 conflict with Smart street and ANM. Both Smart Street and ANM to operate in alternative mode to maintain system stability for NG. Following OC6 operation DNO to maintain system demand so not to cause any change in system state (balance) that may have a negative impact on transmission system.
7	**OC6, CLASS, Smart St and ANM**	**OC6**	OC 6	ACTIVE (DRF/SFR/PFR/DBF/TS)	Alternative mode due to OC6/SS conflict	Alternative mode due to OC6/ANM conflict	OC 6 conflict with Smart street and ANM. Both Smart Street and ANM to operate in alternative mode to maintain system stability for NG. Following OC6 operation DNO to maintain system demand so not to cause any change in system state (balance) that may have a negative impact on transmission system.
8	**Reactive Power Response, CLASS, Smart St and ANM**	**Reactive Power Response**	Reactive Power Response	ENABLED (DRF/SFR/PFR/DBF/TS)	ENABLED	ENABLED	No conflict identified
8	**Reactive Power Response, CLASS, Smart St and ANM**	**Reactive Power Response**	Reactive Power Response	ACTIVE (DRF/SFR/PFR/DBF/TS)	ENABLED	ENABLED	No conflict identified

Table 3: QUEST Use Case Matrix

(yellow)	**Systems not considered in use case**
(green)	**No Conflict**
(red)	**Conflict**
(amber)	**Potential or acceptable conflict**

4.7 QUEST Next Steps

The Use Cases were developed to support the design and specification of the architecture for the QUEST overarching system. These Use Cases will detail what is be expected to work (e.g. what service is to be prioritised and when and how the voltage optimisation systems already in place will interact with each other). The Use Cases will also identify potential areas of conflict and help explore resolutions to avoid them. Each of the Use Case combinations within this report details the overall QUEST system's behaviour.

The next step of this project is the "QUEST System Design and Architecture Lessons Learned". This stage of the project will use the Use Cases to help developed two separate workstreams:

- Workstream 1: architecture options for the QUEST overarching control system.
- Workstream 2: modelling regime based on the Use Case scenarios

Workstream 1 will consist of the software development team (Schneider Electric) developing several different architecture options what will fulfil the specification command arbitration outlined within the Use Cases. These options will then be review and commented on by the wider project team to understand which option is the most viable and robust design option to take forward into the next stage of the project.

Workstream 2 will use the Use Cases scenarios to carry out simulations models to understand the conflicts/resolutions outlined within the Use Cases to prove/disprove the theory within statical modelling techniques, that will help develop and specify the architecture required for the overarching control system. This work will be carried out by the project partner (SGS) with the support and guidance from the wider project team.

5.0 Conclusion

While it remains very early in the project, several early conclusions have been drawn from the development of the initial Use Cases:

- In the Use Cases, wherever potential conflicts arise between system objectives or coordination of system actions, a rule-based approach will be explored further within the next phase of the project. Where a conflict is assumed on trigger, and when the system with the highest priority objective. This approach provides a robust and safe solution for QUEST to implement and meets QUEST's overall objectives. However, this approach may result in long periods where other systems are in this potentially restrictive safe mode, yet the priority system objectives have not been activated, reducing economic or system benefits. Therefore, in future QUEST development, each system mode could be updated to forecast when activation may occur ensuring optimisation of benefits around activation periods.
- Since this is the first-time multiple system objectives will be coordinated together, it is possible unforeseen conflicts will arise. Therefore, flexibility in the use cases must persist during the next project stages, where design and testing of QUEST will allow for identification and resolution of unforeseen conflicts.
- The initial Use Cases are intentionally developed at a high level to allow a degree of flexibility as the QUEST project progresses into the design phase. In particular, the safe modes for each system to cater for conflict will need to be examined in the design phase. QUEST will have an overarching view of network voltage regulation, which may require intervening in ANM control of DER through the issuing of P and Q set points or the issuing of DER P/Q operating envelopes. The design phase for QUEST will need to establish how control and coordination of current and future systems is to be implemented and the supervisory support from these systems and others required.
- It is important to note that the Use Cases are based on known requirements. Should any of these change during the course of the project, the relevant Use Cases will be reviewed and amended as necessary, or new Use Cases will be created to cater for the change in requirements.
- The Use Cases have been developed to demonstrate the objectives of the project to identify and understand opportunities for optimising and coordination of independent systems in delivering an overarching optimisation software sytem. These Use Cases are steppingstones in achieving the project overall objectives as we move into design specification and architectures lessons learned.

APPENDICES

APPENDIX 1 QUEST Actors

Actor	Type	Description
ESO Control Room	Person or System	The ESO Control room can activate/deactivate or request the DSO activate/deactivate CLASS service support including: 1. Demand Reduction Function (DRF) 2. Demand Boost Function (DBF) 3. Tap stagger Function (TSF)
ESO NMS	System	The ESO Network Management System (NMS) provides the ESO Control Room with the status and condition of the National Grid transmission network and allows the ESO Control Room to carry out manual control measures or activate automatic control measures.
DNO Control Room	Person or System	The DNO Control Room can enable/disable and activate/deactivate CLASS service support including: 1. Demand Reduction Function (DRF) 2. Demand Boost Function (DBF) 3. Tap stagger Function (TSF) 4. Load Limiting (LL) 5. The DNO Control Room can also activate/deactivate Smart Street conservation voltage reduction (CVR), request flexible services from the Central ANM NMS and Could ANM and add and enable new DER onto the Central ANM NMS and Decentralised ANM.
ADMS (ENWL NMS)	System	The ADMS system provides the DNO Control Room with visibility of all systems in real time (QUEST Voltage Optimiser, Central ANM NMS, Decentralised ANM, Cloud ANM, Smart Street, CLASS) via the SCADA system; provides the DNO Control Room access to historical data and reports and the ability to simulate future system conditions using the Network Model. The ADMS allows the DNO Control Room to carry out control measures or activate automatic control measures.

QUEST Voltage Optimiser	System	The QUEST Voltage Optimiser is responsible for the co-ordination of existing and future voltage management techniques, establishing efficient network operation, promoting low-cost connection and use of LCTs, to deliver significant customer benefits. The QUEST Voltage Optimiser will: 1. take an overview of the network, in conjunction with forecasted loadings, to control both new and existing intelligent voltage control devices at substations. 2. Continuously monitor the network and adjust its decisions in real-time as conditions change. 3. Use the various voltage management techniques available to balance outputs and adjust voltages to meet user-defined objectives. 4. Create a dispatch schedule for connected DERs that compliments the optimal running arrangement. 5. Enable objectives to be applied to the distribution system as a whole, or to be configured to meet local needs on specific subsets of the system
Central ANM NMS	System	The Central ANM NMS system provides similar functionality to the Decentralised ANM and the Cloud ANM systems but in different locations of the network. The Central ANM NMS monitors the distribution network for thermal limit threshold violations and voltage violations and issues set points to flexible connection DER to modify their import/export to remove the thermal limit violation (similar to the decentralised ANM). In addition, the Central ANM NMS can dispatch DER which have contracted to provide flexible import/export services at pre-agreed prices (similar to the Cloud ANM). The Central ANM NMS uses a merit order list provided by the external Merit Order Management System (MOMS) to dispatch DERs in the most cost-effective way when required. Also, the Central ANM NMS identifies potential future constraint violations within a configurable look ahead period based on forecasted generation and demand levels and produces a list of expected constraint violations together with the associated DERs that could potentially be used to resolve each constraint violation. The output is sent to the MOMS for

		processing and providing the updated merit order list that is used in real-time for constraint violation mitigation. The Central ANM NMS operates independently of the Decentralised ANM and Cloud ANM and on different parts of the network.
CLASS	System	The CLASS system is capable of providing the following services by controlling the voltage at some 350 primary substations using various mechanisms: 1. Demand Reduction Function (DRF). The primary transformers will tap down the system voltage to ~95%, reducing demand. 2. Demand Boost Function (DBF). The primary transformers will tap up to boost the system voltage up to ~1.05%, increasing load and generation export capabilities where export constraints exist. 3. Primary Frequency Response (PFR). Enabled via either the ESO or ENW dashboard. The ASC, which has a frequency relay, will operate automatically on detection of a frequency below 49.8Hz, tripping the LV CB of one of a pair of primary transformers (as long as substation is within its firm capacity). The function will alternate tripping of primary LV CBs. The remaining transformer will have its voltage target reduced to 95%. The estimated demand reduction (PMW) is shown on the dashboard. 4. Secondary Frequency Response (SFR). Enabled via either the ESO or ENW dashboard. The ASC, which has a frequency relay, will operate automatically on detection of a frequency below 49.5Hz, causing both primary transformers to tap down to their lower safe limit. The estimated demand reduction (PMW) is shown on the dashboard. 5. Tap stagger Function (TSF) provides reactive power absorption to reduce NG Transmission system voltages.

		DNO CLASS requirements include: Load Limiting (LL) for Network Reinforcement Deferral. Taps down at individual primary substation transformers to keep peak demand below substation firm capacity.
Smart Street	System	Smart Street utilises advanced real time optimisation software to simultaneously manage high voltage (HV) and low voltage (LV) network assets to respond to customers' changing demands. conservation voltage reduction (CVR) on the LV networks reduce energy demand. On the LV network, controlled meshing of networks releases additional network capacity.
ADMS Network Model	System	The ADMS network model provides the ADMS with calculated data based on real time measurements via the SCADA system and modelled characteristics of the DNO network. Copies of the network model can be taken offline and used to simulate network conditions such as circuit outages and conditions linked to forecasts of generation and demand.
ADMS UI	System	Provides DNO Control Room personnel with access to the ADMS and other systems linked to the ADMS including QUEST Voltage Optimiser, Central ANM NMS, Decentralised ANM, Cloud ANM, Smart Street, CLASS. Also provides the DNO Control Room access to historical data and reports and the ability to simulate future system conditions using the Network Model. The ADMS UI allows the DNO Control Room to carry out control measures or activate automatic control measures.
ADMS Historian	System	The ADMS Historian is a repository for all distribution system operational data including control actions, measurements and events. The Historian is a source of historical data for the DNO Control Room, forecasting systems and other DNO business function reporting.
SCADA	System	The SCADA system links the ADMS and other systems (QUEST Voltage Optimiser, Central ANM NMS, Decentralised ANM, Cloud ANM, Smart Street, CLASS)

		with the DNO network equipment facilitating network control and data acquisition.
Cloud ANM	System	The Cloud ANM can issue dispatch instructions to flexible service provider (FSPs) who have offered flexible services from DER at pre-agreed prices to alleviate network thermal threshold violations. The need for flexible services is forecast ahead of time with dispatch instruction issued in advance based on the forecast requirements. The Cloud ANM and Central ANM NMS operate independently of each other and on different parts of the network.
Aggregator Platform	System	Aggregator system that controls the dispatching of aggregator managed DER assets. The Central ANM NMS flexibility service and Cloud ANM flexibility service will be linked to the aggregator platforms for the provision of flexibility services including dispatch instructions sent to the aggregator platform and DER availability data issued by the aggregator platform.
Aggregator Control Room	Person or System	Aggregator Control Room will oversee the correct functioning of the Aggregator Platform and dispatching of DER assets. Where issues arise the Aggregator Control Room is the point of Contact with the DNO Control Room personnel.
Decentralised ANM	System	The Decentralised ANM will monitor the distribution network for thermal limit threshold violations and issue set points to flexible connection DER to modify their import/export to remove the thermal limit violation (similar to the Central ANM NMS). The Decentralised ANM and Central ANM NMS operate independently of each other and on different parts of the network.
ANM	System	ANM is used to represent all three ANM systems described above (Central ANM NMS, Decentralised ANM and Cloud ANM). All three ANM systems operate

		independently of each other. The Central ANM NMS will operate on different areas of the distribution network from the Decentralised ANM and Cloud ANM
ANM Local Micro RTU	System	Provides the local DNO ANM interface with the individual flexible connection DER asset control systems. This allows the ANM system to issue import/export set points to the DER asset, receive DER measured data and provide failsafe controls should communications with the DER fail.
ANM DER	System	ANM DER are flexible connection assets that can be controlled by the Central ANM NMS or Decentralised ANM to curtail and release power import/export when required to keep the DNO network operating within thermal limits.
ANM DER Control Room	Person or System	ANM DER Control Rooms will oversee the correct functioning of the flexible connection DER assets. Flexible connection DER assets controlled by the ANM may have individual owners with their own control rooms or individual owners that use third party control room services. Where issues arise the relevant ANM DER Control Room is the point of Contact with the DNO Control Room personnel.
Substation RTU	System	DNO substation RTU which is used to communicate with the substation equipment associated with ADMS, QUEST Voltage Optimiser, CLASS, Smart Street, and the Central ANM NMS.
EAVC Relay	System	This is the substation enhanced automatic voltage control system which operates on-load tap changers (OLTCs) to regulate the network voltage to desired voltage level. The 'enhanced' element indicates that it is capable of and responsible for delivering CLASS services.
OLTC (On-Load Tap Changer)	System	The OLTC in this instance is associated with Smart Street where voltage regulation has been added to existing 11/0.4kV substations.
Non-ANM DER	System	DER assets that are no part of ANM flexible connections.

Non-ANM DER Control Room	Person or System	Where relevant this is a Control Room associated with DER assets that are no part of ANM flexible connections.
DNO Operational Personnel	Person	DNO operational personnel outside of the DNO Control Room that are required to enable any of the control systems (SCADA, Smart Street, CLASS, Decentralised ANM, Central ANM NMS).