QUEST

Trial Design Report

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Life Is On | Schneider Electric

Revision History

Version	Authors	Date	Comments
1.0	Gordana Simić	26-May-2022	Initial version of the QUEST Trial Design Report.
1.1	Milena Jajčanin, Marko Čomić	27-May	Revision and update
1.2	ENWL, SGS	30-May-2022	Revision
2.	Milena Jajčanin	8-June-2022	Update based on the comments received from ENWL and SGS

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1. ABBREVIATIONS

Abbreviation	Description
ANM	Active Network Management
AOR	Area of Responsibilities
BSP	Bulk Supply Point
BSP TSF	Tap Stagger Functionality on a BSP level
CE	Control Engineer
CLASS	Customer Load Active System Services
CLASS-DR-MM	CLASS Demand Reduction Mitigation Mode
CLASS-DB-MM	CLASS Demand Boost Mitigation Mode
CMP	Contention Management Process
DB	Demand Boost (CLASS Function)
DER	Distribution Energy Resource
DR	Demand Reduction (CLASS Function)
DRF	Demand Reduction Full (CLASS Function)
DRTQ	Demand Reduction Three Quarters (CLASS Function)
DRH	Demand Reduction Half (CLASS Function)
DROQ	Demand Reduction One Quarter (CLASS Function)
ENWL	Electricity North West Ltd.
ICCP	Inter-Control Center Communication Protocol
LFDD	Low Frequency Demand Disconnection
LFDD-MM	Low Frequency Demand Disconnection Mitigation Mode
NE	Network Efficiency
NEM	QUEST's Network Efficiency Mode
NMS	Network Management System
NSS	Network State Simulator
OC6	Grid operating code 6
OC6-MM	OC6 Mitigation Mode
OC6-VR-MM	OC6 Voltage Reduction Mitigation Mode
OC6-DD-MM	OC6 Demand Disconnection Mitigation Mode
RT	Real Time
SE	Schneider Electric

SMST	Smart Street
SYSCON	System Condition
TPL	Technique Priority List
TSF	Tap Stagger (CLASS Function)
VM	Virtual Machine
VLAN	Virtual Local Area Network

2. REFERENCES

#	Title	Description
1.	QUEST an Overarching Control System, QUEST Initial Report - Use Cases	ENWL document "QUEST an Overarching Control System, QUEST Initial Report - Use Cases", Issue: 1, Submission Date: 30th July 2021", available at: https://www.enwl.co.uk/globalassets/innovation/quest/documents/quest-initial-report_use-cases-issue1.pdf.
2.	QUEST Architecture Options - Subphase 1 Report	Document providing the review of subphase 1 of the QUEST detailed design. Within this document, QUEST use cases are additionally clarified, and QUEST functionality is determined. Inputs from this document are crucial for determination of QUEST architecture options.
3.	QUEST Architecture Options – Subphase 2 Report	Document providing the review of subphase 2 of the QUEST detailed design. Within this document, QUEST Architecture Options are determined.
4.	Functional Specification for the Chosen Architecture – subphase 1 report	Document providing the review of subphase 1 of the Functional Specification for the Chosen Architecture phase of QUEST detailed design. Within this document, additional functionality introduced in QUEST architecture is described. Based on the agreements made during this subphase, this document is finalized.
5.	QUEST Functional Specification	Document describes final QUEST functionality agreed during design phases 1&2.

3. INTRODUCTION

The purpose of this document is to provide a detailed overview of the testing strategy that will be applied during the QUEST trials. Within this document the high-level description of the use cases, based on which QUEST functionality will be assessed during the trials. The purpose of these use cases is to provide a way to confirm that the implemented QUEST functionality captures all the agreements made during the QUEST design and that QUEST satisfies all its objectives defined so far.

Please note that the use cases provided within this document are completely different to the ones initially defined within the “QUEST an Overarching Control System, QUEST Initial Report - Use Cases” [1]. The purpose of the first version of QUEST’s use cases was to define all the possible conflicts that could happen between the different voltage control techniques and to define the requirements for coordination between them. By defining the first version of the QUEST use cases, a foundation for the further phases of the QUEST design was provided. Through these further phases of QUEST design, the use cases were further refined. Based on all the conclusions made within these phases, QUEST’s architecture is established. More details regarding the conclusions made for each use case are provided in “QUEST Architecture Options - Subphase 1 Report” [2] and “QUEST Architecture Options – Subphase 2 Report” [3]. The use cases provided within this document are not focused on the conflicts between the different voltage control techniques, but on the agreed QUEST’s functionality. However, for each use case provided in this document, it is noted to which conflict from the initial version of the use cases it refers to. This is done to make sure that all the conflicts that were discussed initially are covered through the agreed QUEST’s functionality. Additionally, a reference to the test plans that will be created by other partners (SGS, Fundamentals) is also provided along the newly created QUEST use cases. These test plans will describe the enhancements made within external systems (Cloud ANM, Decentralised ANM, SuperTAPP SG Relay) in order to support the agreed QUEST architecture. Each QUEST use case describing QUEST’s integration with the external ANM systems and enhancements of SupperTAPP SG Relay contains a note referencing these additional test plans.

In addition to the use cases, within this document, a summary of QUEST’s functionality is provided in “Overview of the Agreed QUEST Functionality” section which is followed by the “QUEST Use Cases” section. After that QUEST Testing phases timeline is provided.

QUEST testing strategy is additionally explained through “QUEST Testing Environment” and “QUEST Installation” sections. Towards the end of the document, a list of modelling studies that need to be performed prior to the QUEST operational trials is provided in section “Network modelling studies needed for QUEST trials.”

4. OVERVIEW OF THE AGREED QUEST FUNCTIONALITY

QUEST software is developed as a part of EcoStruxure ADMS solution (v3.7.2) and relies on its infrastructure.

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

The voltage management techniques coordinated by QUEST are:

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

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

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

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

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

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

To satisfy its objectives, QUEST operates in real time.

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

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

Another QUEST core objective is to enhance operational efficiency, under normal system conditions, by minimizing the 33kV system losses. For that purpose, an additional voltage control technique, Network Efficiency Mode (NEM) technique, is introduced through QUEST overarching software. NEM endeavours to minimise 33kV system losses by raising the target voltage values on 132/33kV transformers, while maintaining voltages within its statutory defined limits.

In addition to satisfying its defined objectives, QUEST also enhances the CLASS functionality. As an overarching software that has awareness of all other voltage control techniques operating in the network. QUEST can therefore correctly adjust the CLASS primary substations’ function (voltage) levels in order to satisfy CLASS committed targets, whilst simultaneously trying to minimise its effect on other voltage control techniques. Also, QUEST introduces additional levels of voltage reduction for CLASS primaries, as well as the Tap Stagger Functionality on a BSP level (BSP TSF).

More details regarding the agreed QUEST functionality are provided in ‘QUEST Functional Specification’ [5].

5. QUEST USE CASES FOR OPERATIONAL TRIALS

As described in the Introduction, the use cases outlined within this document differ from the ones created initially which are described in [1]. Eight use cases were initially developed, and they outlined the scenarios of the individual voltage control and optimisation systems running in different operating modes. They were created to allow the development and design of QUEST architecture options and network modelling requirements. These use cases were used as a starting point for the later phases of the QUEST design through which the QUEST overarching software functionality was established. Bearing that in mind, these use cases were further refined and updated throughout these phases of the project.

The list of the initial QUEST use cases is provided below:

Normal non-emergency running

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).

NG ESO responses

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.

As it can be seen from the use cases' titles, they are focused on the detection of the conflicts between different voltage control techniques and how these techniques could conflict with the provision of the NG ESO responses.

As described in section 4 "Overview of the Agreed QUEST Functionality", through the definition of the QUEST's architecture, QUEST's behaviour under normal and emergency system conditions has been determined. QUEST system behaviour, under normal system conditions (SYSCON 6), is covered by initial use cases 1-5. The QUEST's functionality in emergency system conditions (SYSCON 1-5) is covered by initial use cases 6-7.

Additionally, enhancement of CLASS functionality is introduced into the QUEST overarching software system by the addition of the BSP TSF TECHNIQUE. BSP TSF delivers reactive response to the ESO. This functionality is covered by the initial use case 8.

To capture the agreed QUEST functionality during the QUEST operational trials, 8 new use cases are introduced. These use cases are as follows:

- UC1: QUEST Configuration – Create a QUEST profile,
- UC2: QUEST Simulation – Inspect results of QUEST Contention management process; *UC1 extension*,

- UC3: QUEST Control – Start QUEST RT coordination on a GSP level – In normal condition; *UC2 extension*,
- UC4: QUEST Control – QUEST on a GSP level reacts on detected events – In normal conditions; UC3 extension,
- UC5: QUEST Control – Transition from Normal to Emergency system state; *UC3 extension,*
- UC6: QUEST Control – Transition from Emergency to Normal system state; *UC3 extension,*
- UC7: CE blocks NEM on a BSP level,
- UC8: QUEST coordination in case of BSP TSF enablement/activation.

The main purpose and high-level description of each use case is given below. Detailed description of use cases, in 'step by step' form, will be provided afterwards through the creation of the test plan for project testing phases. Additionally, each use case will be divided into several separate test cases which will be used to assess QUEST functionality in more details, during the test phases of the project.

5.1. UC1: QUEST Configuration – Create a QUEST profile

The main purpose of this use case is to show the process of QUEST PROFILE creation.

QUEST PROFILE contains all the inputs provided to QUEST overarching software by the QUEST control engineer (CE). Through QUEST PROFILE coordination type (responsive or proactive) is configured, as well as the priorities of voltage control techniques and their desired function levels. More details regarding QUEST configuration are provided in [5].

The high-level steps of this use case are provided in the remainder of this sub-section.

The CE creates a new PROFILE through the QUEST PROFILE Editor window. In that window, CE selects coordination type: 'Responsive (Fast Tap)' or 'Proactive (Technique priority list)'. If 'Proactive (Technique priority list) is selected, the CE sets the TPL order and desired Function Level for the voltage control techniques. The QUEST PROFILE can then be saved, and only the saved ones are available in the QUEST PROFILE list. Saved profiles can be used now or later, for the QUEST CMP or QUEST Real Time (RT) operation.

Please note that it will be a business procedure to define which users will have the appropriate permissions for QUEST PROFILE creation and approval. It is assumed that the QUEST CE will be the one who creates QUEST PROFILES and approves them. The other CE's will be able to apply and run previously created and approved QUEST PROFILES for starting the QUEST RT operation. The other CE's will follow an operational business procedure that will instruct them which pre-defined QUEST PROFILES to apply/run on the electricity system according to the time (hour/day/season) and operating conditions.

5.2. UC2: QUEST Simulation – Inspect results of QUEST Contention management process; *UC1 extension*

Prior to starting QUEST's RT operation, the QUEST CE performs offline analysis (called Contention Management Process (CMP)) to determine what is the most suitable QUEST PROFILE configuration. This use case shows how the QUEST CE can perform that analysis.

Firstly, the CE selects one of the previously created PROFILEs (UC1). Thereafter, the simulation can be started, and QUEST generates the results. The results are available in the Outcome report. In the results, the QUEST CE can observe achieved benefits for each of the voltage control techniques and compare them to the configured adjustment of TPL and Function Levels. The QUEST CE concludes whether the QUEST PROFILE configuration is acceptable, or some fine tuning of the Function Levels should be performed through another CMP cycle.

Note: QUEST CMP does not affect QUEST's operation in real time. This use case is applicable only during the Normal system conditions. This functionality is not available during the Emergency conditions.

5.3. UC3: QUEST Control – Start QUEST RT coordination on GSP – In normal condition; *UC2 extension*

The main purpose of this use case is to show how the QUEST RT control can be started during the Normal system state, after the offline studies are performed and the most suitable QUEST PROFILE configuration is determined (UC2).

Before it is started, one of the previously created PROFILEs (UC1) should be applied for QUEST RT Control. Thereafter, QUEST RT Control can be started for a GSP area. At that moment, QUEST automatically starts to perform the coordination based on the configured TPL and Function Levels. When QUEST RT Control is activated, the results are shown in the QUEST Dashboard and appropriate actions are sent to the devices (BSP transformers, CLASS primaries, SMST transformers). The QUEST Dashboard shows the relevant data for each voltage control technique that QUEST coordinates, as well as the key performance indicators through which benefits of QUEST real time operation can be observed. QUEST's actions in RT can be tracked in the Event Summary as well.

During the further phases of QUEST trials definition this use case will be divided into several test cases where different technique priorities and function levels will be assessed. By defining the different priorities among the voltage control techniques, initial use cases 1-5 will be covered. Also, all the workflows provided within the Appendix section of the QUEST FS [5] will be assessed. Within these test cases a step-by-step instruction and the expected results of these tests, will be provided.

NOTE: In collaboration with Fundamentals, additional test cases will be written based on this use case to cover the enhancements of SuperTAPP SG Relay that will be made to support additional levels of CLASS demand reduction (DRTQ and DROQ levels). SE will cover the test cases describing QUEST's behaviour and enablement of these newly introduced levels of CLASS DR. These test cases will be integrated into combined test cases that will be used in QUEST operational trials in a production environment.

5.4. UC4: QUEST Control – QUEST on GSP reacts on detected events – In normal conditions; *UC3 extension*

The purpose of this use case is to show that QUEST, when performing coordination in RT during normal system state, reacts on:

- The change of CLASS half-an-hour targets,

- The change of CLASS primary substations' availability status (inhibited, test, contribution is changed to zero),
- The change of CLASS function status (e.g., CLASS status changes from Enabled to Activated),

If any of these events happens, QUEST RT control will be re-triggered. It means that UC3 scenario will be repeated.

In a case of CLASS half-an-hour target change, QUEST calculates a new schedule to enable CLASS primaries and SMs for other techniques, based on the TPL, Function Levels, and a new CLASS target. When any of the CLASS primaries becomes unavailable (inhibited, test, contribution is changed to zero), QUEST will not consider it. In a case of CLASS status changes from Enabled to Activated, QUEST sends appropriate MM to ANM systems. All these situations, and expected QUEST behaviour, will be described in detail during the creation of several test cases that will refer to this use case.

NOTE: In collaboration with SGS, additional test cases will be written based on this use case to cover the integration of QUEST with Cloud and Decentralised ANM via ICCP. SGS will cover the test cases describing the expected behaviour of the Cloud ANM and Decentralised ANM systems when QUEST sends them commands to transit to alternative modes of operation as defined in the QUEST design. SE will cover the test cases describing QUEST's behaviour and sending the appropriate commands to SGS's ANM systems. These test cases will be integrated into combined test cases that will be used in QUEST operational trials in a production environment.

5.5. UC5: QUEST Control – Transition from Normal to Emergency system state; UC3 extension

The purpose of this use case is to show that QUEST, when performing coordination in RT during normal system state, triggers when system state is changed to emergency (SYSCON 2/3/4/5). If emergency condition happens in the network, the QUEST CE will manually start appropriate emergency system state in QUEST Control & Monitoring window, for QUEST to be aware of it.

In emergency system state QUEST does not perform coordination based on the configured TPL and Function Levels. Instead, QUEST sends appropriate Mitigation Modes (MM) to the other techniques (to prevent them counteracting the provision of the emergency response services). The meaning of MM for each voltage control technique is determined during the creation and refinement of the initial version of QUEST use cases (use cases 6 and 7). Having that in mind, this high-level use case captures the initial use cases 6 and 7.

In the case of activating OC6 VR (SYSCON 5), QUEST sets OC6-VR-MM for ANM, NEM & SMST, and sends appropriate actions. When OC6-DD (SYSCON 4) is activated, QUEST sets OC6-DD-MM for ANM, NEM & SMST, and sends appropriate actions. When LFDD (SYSCON 2/3) is activated, QUEST sets LFDD-MM for ANM and NEM and sends appropriate actions.

NOTE: More details about expected actions, when MM is set, is given in 'QUEST Functional Specification' [5]. Through the creation of the detailed QUEST test cases, these detailed steps and expected results will be stated.

5.6. UC6: QUEST Control – Transition from Emergency to Normal system state; UC3 extension

The purpose of this use case is to show the process of transitioning from emergency condition (SYSCON 2/3/4/5) back to the normal system state (SYSCON 6) is performed and to describe how QUEST behaves in this transitioning process. When the emergency system state is over, the QUEST CE manually starts the normal system state in QUEST Control & Monitoring window, for QUEST to be aware of it. When the QUEST CE tries to change the system state in QUEST Control & Monitoring window, the CE gets the message through a pop-up window to confirm its decision to change the SYSCON from an emergency to a normal condition.

Once the system state is changed, QUEST RT control is re-triggered. The ANM is returned in a normal mode of operation. In accordance with techniques' priorities and function levels, NEM BSPs are set to a level of voltage increase, SMST transformer get appropriate level of CVR, and CLASS gets a new schedule to enable primaries.

5.7. UC7: CE blocks NEM on a BSP

The purpose of this use case is to show how the QUEST CE can manually exclude a particular BSP from NEM consideration. To achieve that, QUEST CE changes NEM status on a BSP to blocked from QUEST Control & Monitoring window. When NEM status is blocked, for a BSP, QUEST sends an action for that BSP transformer to return to its default setting (maintain nominal 33 kV voltage). QUEST will not consider BSP blocked for NEM, until the QUEST CE removes blocked status from that BSP.

This use case reflects the QUEST functionality introduced based on the requirements defined within the Initial use case 1.

5.8. UC8: QUEST coordination in case of BSP TSF enablement/activation

The main purpose of this use case is to show the introduction of CLASS enhancement related to BSP TSF through the QUEST overarching software. It is also intended to assess how QUEST reacts in a case when BSP TSF gets enabled/activated. BSP TSF enablement/activation is considered in two scenarios:

- QUEST RT control is already active in the moment of BSP TSF enablement/activation.
- QUEST RT control is started after BSP TSF enablement/activation.

The description of QUEST functionality that is covered through this use case is provided in the remainder of this sub-section.

The QUEST CE can enable BSP TSF through the enhanced CLASS Dashboard within the QUEST environment, regardless of the QUEST RT activation status. When QUEST RT is already started, the QUEST intervention depends on the technique's priorities defined through QUEST PROFILE. If BSP TFS has priority over NEM, in case of conflict detection, QUEST automatically transits NEM into the next lower level of voltage increase to provide the possibility of performing reactive power response via BSP TSF. In case that NEM has priority over BSP TSF, that means that the level of NEM cannot be automatically readjusted upon BSP

TSF enablement. It that situation, QUEST reports the appropriate message to the QUEST CE informing them that the chosen stage of BSP TSF is not feasible due to applied NEM level.

QUEST is triggered on BSP TSF enablement when BSP TSF has priority over NEM and the current level of NEM conflicts with the required level of BSP TSF. QUEST is triggered to readjust the level of NEM.

In situation when BSP TSF is activated on a particular BSP, prior QUEST RT operation is started, BSP TSF on that BSP is treated as highest priority regardless of the TPL defined through QUEST PROFILE.

This use case reflects the QUEST functionality introduced based on the requirements defined within the Initial use case 8 that describes the provision of reactive power response to NG ESO.

NOTE: In collaboration with Fundamentals, additional test cases will be written based on this use case to cover the enhancements of SuperTAPP SG Relay that will be made to support TSF on a BSP level functionality. SE will cover the test cases describing QUEST's behaviour and enablement/activation of BSP TSF. These test cases will be integrated into combined test cases that will be used in QUEST operational trials in a production environment.

6. TESTING PHASES TIMELINE

According to the project plan, after the QUEST design, development and prototype presentation, acceptance testing phase will be performed. High level project plan is given in the figure below.

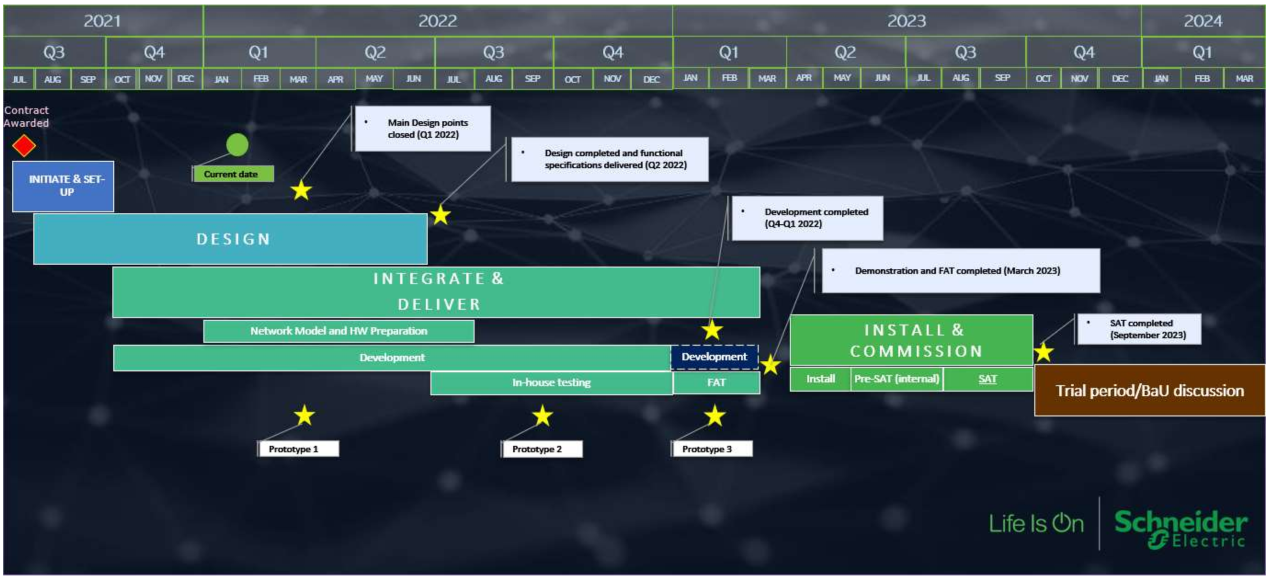

Figure 6.1 – QUEST project timeline

As illustrated in the Figure 6.1, acceptance testing will be divided into four key phases:

- Pre-Factory Acceptance Testing (Pre-FAT) (Internal, preparatory tests),
- Factory Acceptance Testing (FAT),
- Pre-Site Acceptance Testing (Pre-SAT) (Internal, preparatory tests),
- Site Acceptance Testing (SAT).

Each of these phases usually consists of three parts:

- Preparation -software update deployment, system check, etc.,
- Execution - executing the test cases and unstructured testing,
- Issue Resolution -defect fixing and verification, re-executing the failed/blocked test cases.

The QUEST functionality will be assessed in a comparable way, depending on the testing phase:

1. Pre-production,
2. Production.

Pre-production and production testing phases are described in the following section.

7. QUEST TESTING ENVIRONMENT

QUEST solution will be deployed on a separate physical server or virtual machine (workstation), called 'QUEST Server' in the following text.

The 'Real Time – Hot server' in production environment (PST2) and 'QUEST server' in QUEST environment are shown in Figure 7.1 –QUEST testing environment During the **pre-production** testing phases, this testing strategy will be used. QUEST Server will be completely detached from the PST2 system. Depending on system quality and other prerequisites, such as availability of live testing equipment (for example, generators) among others, the project team will plan to do live tests in the preproduction phase as well. In this case, if this decision is made, the strategy for pre-production tests that will be applied is the same as for production tests.

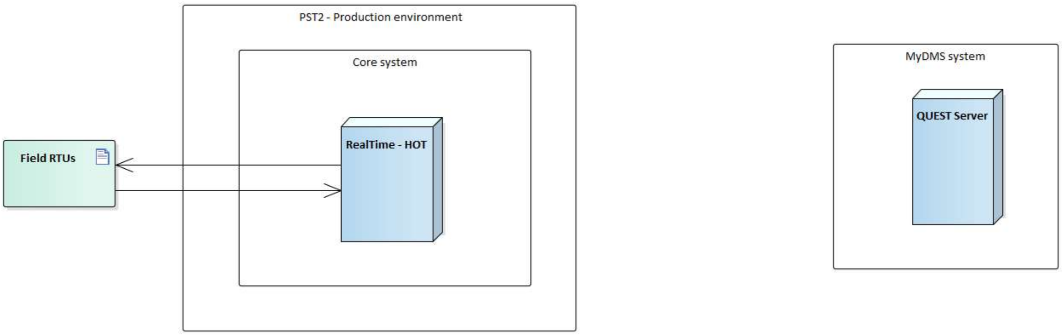

Figure 7.1 –QUEST testing environment for pre-production

The SE EcoStruxture ADMS solution is installed on both servers, but different installations are used: NMS project installation in the PST2 system, and QUEST installation in the QUEST environment. More details regarding the difference between these installations are given in the QUEST Installation section.

Although QUEST environment is separate from PST2, QUEST functionality will be assessed in production, as well, but in the following way: QUEST Server will have connectivity to the production system (field) through the ICCP. That will be the QUEST testing strategy for **production**, and it is shown in Figure 7.2.

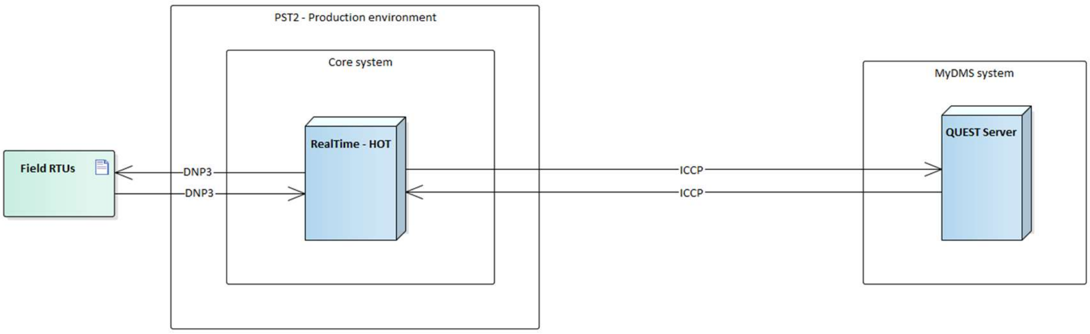

Figure 7.2 – QUEST testing environment for production

In the following sub-sections, the QUEST environments for pre-production and production testing phases are described in more details.

7.1. QUEST pre-production phase

During the pre-production testing phase, QUEST server will not communicate with the PST2. For this phase only QUEST environment is of interest. QUEST deployment configuration is shown in Figure 7.3.

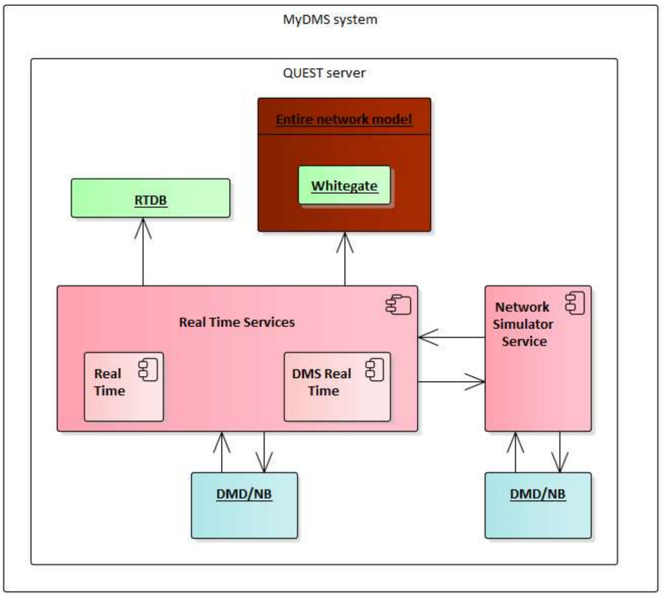

Figure 7.3 – QUEST pre-production, deployment configuration

This deployment configuration is used during the development process (when there is no live data feed from the SCADA) but will also be used during the pre-production testing phase. In this configuration Real Time Services, within the QUEST server, are configured to receive field values from Network State Simulator (NSS). NSS is responsible for simulation of grid behaviour.

Figure 7.4 illustrates how communication between the ADMS Real time service and the ADMS Network Simulator is established.

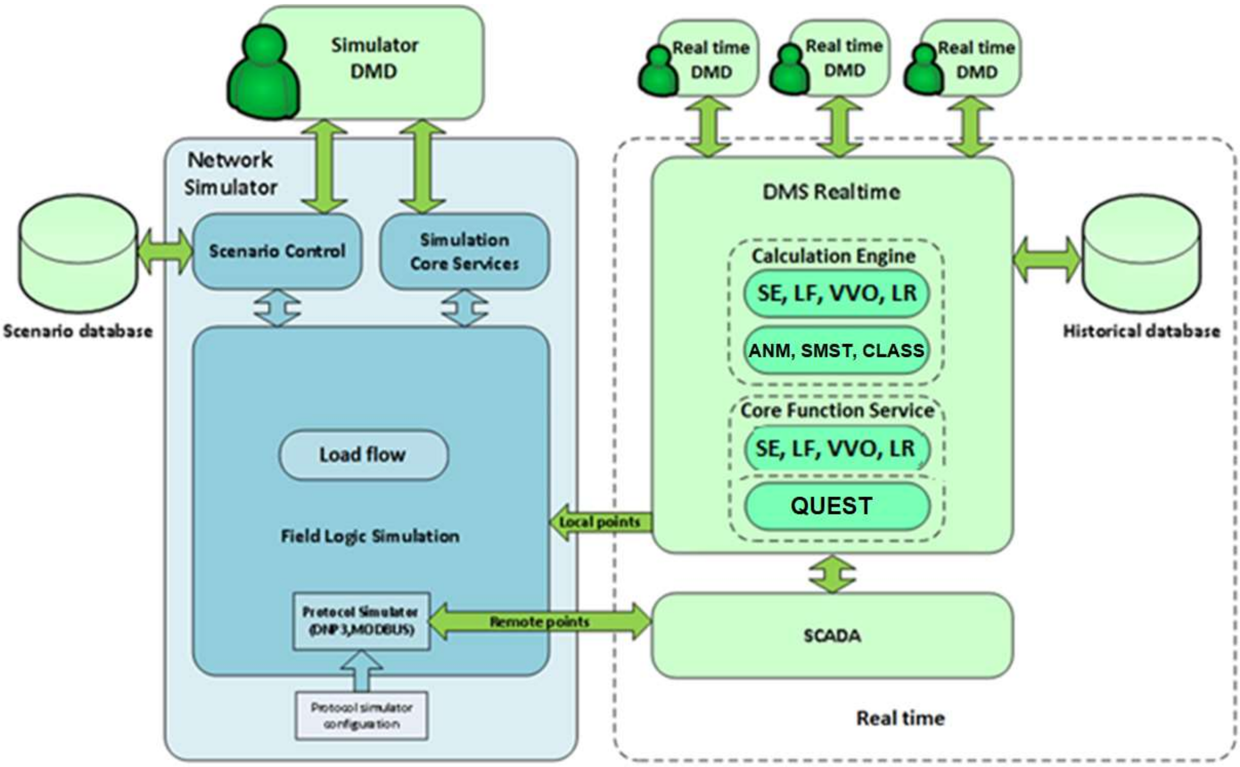

Figure 7.4 – Communication between ADMS RT and ADMS NS services

The working principle of the Network Simulator is almost the same as of the ADMS Realtime. Almost all services that run in the ADMS Realtime also run in the ADMS Network Simulator. On the simulator side, LF calculation is executed, and appropriate measurements are written in SCADA. That information is then sent to real-time and can be used by ADMS. The only way of communicating between simulation and real-time is using SCADA points. Each time new optimal SPs are calculated on the real-time side, those set points are sent to the simulator. The simulator runs LF upon detecting setpoint change and sends new measurements back to real-time.

QUEST server will be able to command only Whitegate GSP area, which will be used for QUEST functionality testing.

Windows desktop applications such as DMD and NB can be run on QUEST Server to enable user monitoring and control in the network.

NOTE: Additional discussions need to be performed to determine how to assess the integration with SGS's ANM systems in the pre-production phase using the Network Simulator (test cases related to SGS ANM systems coordination that will be written based on the UC4). Sending the commands by QUEST for transitioning SGS's ANM systems will be possible to assess. However, it will need to be determined how to simulate SGS's ANM systems behaviour and the impact of their actions on the network state since the Network Simulator is not aware of these external systems.

7.2. QUEST production phase

For production phase, QUEST Server will communicate with PST2, through ICCP. Figure 7.5 shows deployment configuration of QUEST solution for production. Since these systems are in communication, both PST2 and QUEST environment are of interest for this phase of QUEST trials.

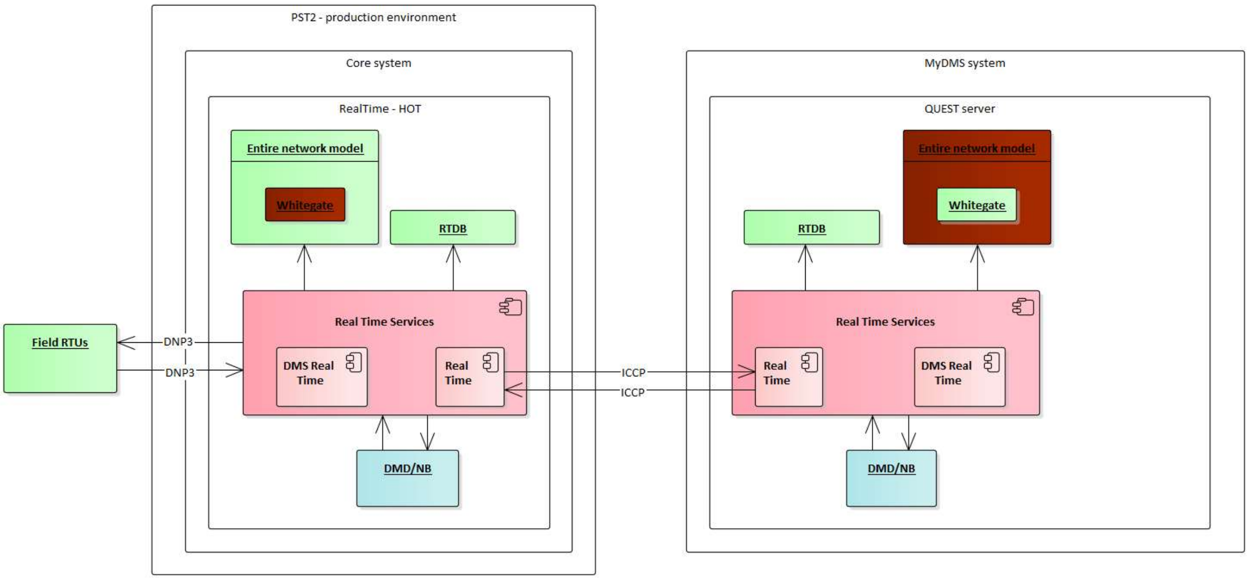

Figure 7.5 - QUEST production, deployment configuration

In this deployment configuration, Real Time Services, within the QUEST Server, are configured to communicate with Real Time Services, deployed in the NMS production system. The QUEST Server receives SCADA values for signals of interest (under Whitegate area) from NMS productional core system through the ICCP. Commanded values for signals of interest (under Whitegate area) are exported from QUEST Server to the production system using the ICCP protocol as well.

This configuration requires that Whitegate GSP area is not controlled by the productional Real Time Services. It means that ANM and SMST will be turned off for the Whitegate area on the NMS production system, during the QUEST trials. The CLASS Scheduler, which operates on the entire network, will be turned off on the NMS production system. Whitegate GSP area will be controlled from the QUEST Server. It means that ANM and SMST will be turned on within the QUEST server. CLASS scheduling will be performed on the QUEST Server side during the QUEST trials. The scheduling process will be performed either by QUEST or by the CLASS scheduler (the one deployed within QUEST Server not the BAU NMS production system CLASS scheduler). Based on the type of coordination performed by the QUEST, it is determined who is in charge for CLASS primaries enablement. More details regarding this in QUEST Functional Specification [5].

Since the QUEST environment will have connectivity to the field through the ICCP it should be considered as a part of the production system. Therefore, certain security aspects (rules) must be complied with. Architecture will implement the same security principles as all the ADMS Systems do:

- Physical access - Access to the QUEST hardware should be restricted, same as for the rest of the ADMS Systems hardware.

- Network traffic - QUEST environment will reside in an isolated VLAN, traffic between environments will go via firewall and it will be controlled by firewall rules.
- Anti-virus and malware protection - Anti-virus software will be installed.
- Authentication - Windows Integrated authentication will be used, same as in the rest of the ADMS Systems.
- Authorization - User access will be controlled and restricted by using Role-Based Access Control and AOR management. QUEST environment will not be a part of any existing Active Directory (AD) domain. Either new Workgroup or a new AD domain will be set up for QUEST VM. ADMS GPO will be applied.
  ICCP communication - Certificate will be used in ICCP communication between QUEST and PST2.

In case any issue is noticed during preparations for the production testing phase, the parts that are unavailable or not possible to be made part of the live tests will be exchanged with simulators. The project team will put in all reasonable efforts to enable complete live tests in this testing phase.

8. QUEST INSTALLATION

As explained earlier, QUEST will be deployed on a system separate from NMS and will not affect the NMS production code, only the communication between these two systems will be established during the production phase. Within the QUEST environment, it is permissible to amend the existing algorithms for the purposes of the QUEST trials.

Central ANM will be enhanced within the QUEST environment to support new modes of operation, which will be set when QUEST detects conflict between ANM and other techniques. The Central ANM version that will be rolled out in the production within the NMS project will not be changed.

CLASS will also be enhanced within the QUEST environment. Several CLASS functionalities will be enhanced:

- CLASS scheduling functionality,
- Implementation of CLASS DB targets,
- Additional levels of CLASS DR (DROQ, DRTQ),
- TSF on BSP level.

Testing of these CLASS enhancements will be performed on the QUEST environment.

More details about previously mentioned enhancements are given in the QUEST Functional specification [5].

9. NETWORK MODELLING STUDIES NEEDED FOR QUEST TRIALS

In addition to QUEST Architecture Options track where QUEST functionality and architecture are further refined, network modelling studies were performed in parallel by SGS to confirm the need for QUEST operation. All conflicts between the different voltage control techniques which should be prevented by QUEST's operation were discussed only in theory within the QUEST architecture options track. The first goal of the Network Modelling Regime track is to prove that these conflicts exist by performing the offline analysis. The second goal is to determine parameters that will be required when setting up the QUEST software for operational trials.

The simulation studies performed during the Network modelling regime track held during the second phase of the QUEST project are continued in the third phase of the QUEST project within the Voltage Control Methodology track.

The parameters that are needed for QUEST operational trials are detected within the QUEST Architecture Options track (reports [2] and [3]) and Functional Specification for chosen architecture track (reports [4] and [5]). The purpose of this section is to list all the simulation studies that are needed to be performed prior QUESR operational trials.

9.1. The list of the modelling studies needed for QUEST trials

Based on all conclusions from the QUEST architecture options track and the Functional Specification for chosen architecture track, the summarised list of the modelling studies is provided below.

9.1.1. Additional levels of CLASS demand reduction

Summary of CLASS Demand Reduction functions (original and proposed):

- DRF – Demand reduction full: Target = 5%, +/-0.7%, provides a 5.7% - 4.3% voltage reduction.
- DRTQ – Demand reduction three quarters: Target = 4%, +/-0.7%, provides a 4.7% - 3.3% voltage reduction.
- DRH – Demand reduction half: Target = 3%, +/-0.7%, provides a 3.7% - 2.3% voltage reduction.
- DROQ – Demand reduction one quarter: Target = 2%, +/-0.7%, provides a 2.7% - 1.3% voltage reduction.

All simulations performed so far considered only two levels of CLASS demand reduction (DRF and DRH). The newly introduced levels of voltage reduction (DRTQ and DROQ) should also be considered in all the simulations presenting the conflicts between different voltage control techniques.

9.1.2. Smart Street safe target voltages

In the rest of this paragraph all SMST safe modes are listed as well as the safe target voltages that should be determined per each safe mode.

SMST % levels of LV efficiency determined based on levels of CLASS demand reduction are as follows:

- **75% LV efficiency - CLASS-DROQ-SM** - this percentage of LV efficiency means that SMST is put in a safe mode that corresponds to CLASS-DROQ enablement - the highest level of voltage reduction on SMST transformers, since the lowest level of voltage reduction (one quarter) is applied to associated CLASS primaries.

- **50% LV efficiency - CLASS-DRH-SM** - this percentage of LV efficiency means that SMST is put in a safe mode that corresponds to CLASS-DRH enablement.
- **25% LV efficiency - CLASS-DRTQ-SM** - this percentage of LV efficiency means that SMST is put in a safe mode that corresponds to CLASS-DRTQ enablement.
- **0% LV efficiency - CLASS-DRF-SM** - this percentage of LV efficiency means that SMST is put in a safe mode that corresponds to CLASS-DRF enablement. It should be confirmed during the simulation studies whether there is any room for performing voltage reduction on SMST transformers when CLASS DRF is activated, or these transformers should be set to their default target voltages without performing any voltage reduction.

100% level means that SMST is performing in CVR mode, and that no safe mode is applied by QUEST.

Based on the CLASS DB levels supported though the SuperTAPP Relay, the SMST allowed levels (safe modes) are defined as follows:

- **0% – CLASS-DBF-SM –** this percentage of LV efficiency means that SMST is put in a safe mode that corresponds to CLASS DBF enablement. The target voltage is determined in a way not to have LV voltage violations upon CLASS DBF deactivation.
- **50% – CLASS-DBH-SM –** this percentage of LV efficiency means that SMST is put in a safe mode that corresponds to CLASS DBH enablement. The target voltage is determined in a way not to have LV voltage violations upon CLASS DBF deactivation.

100% of LV efficiency means that SMST is performing in CVR mode and that no safe modes are applied by QUEST. SMST is allowed to operate in CVR mode on all distribution transformers supplied from primary substations that do not have CLASS demand boost enabled.

NOTE: 25%, 75% levels of LV efficiency are not supported in case of SMST coordination with CLASS DB since additional levels of DB are not introduced in this version of QUEST project.

9.1.3. NEM safe target voltages

Similar to SMST, NEM % levels of max 33kV efficiency are determined based on CLASS DR adjustement and are as follows:

- **100% of 33 kV efficiency - NEM Full** (e.g., 105% voltage target for 100% achievable 33kV efficiency in terms of network losses), no safe mode applied to NEM.

  For determining target voltage for the Normal mode of operation simulation studies should cover different scenarios to determine critical periods of the day when over-voltages may occur if maximum level of voltage increase is applied (e.g., during extremely low load periods). These studies should provide inputs regarding either maximum allowed levels of voltage increase in Normal mode of operation that will never cause over-voltages or periods of the day when network efficiency should not be run.

- **75% of 33 kV efficiency - CLASS-DROQ-SM** - this percentage of max 33kV efficiency means that NEM is put in a safe mode that corresponds to CLASS-DROQ enablement - the highest level of voltage increase on BSP transformers, since the lowest level of voltage reduction (one quarter) is applied to associated CLASS primaries.

- **50% of 33 kV efficiency - CLASS-DRH-SM** - this percentage of 33 kV efficiency means that NEM is put in a safe mode that corresponds to CLASS-DRH enablement.
- **25% of 33 kV efficiency - CLASS-DRTQ-SM** - this percentage of 33 kV efficiency means that NEM is put in a safe mode that corresponds to CLASS-DRTQ enablement.
- **0% of 33 kV efficiency - CLASS-DRF-SM** - this percentage of 33 kV efficiency means that NEM is put in a safe mode that corresponds to CLASS-DRF enablement. In this situation it is assumed that NEM will not be applied to provide enough room for DRF to be applied on primary transformers. It should be confirmed during the simulation studies whether there is any head room for performing voltage increase on BSP transformers when CLASS DRF is activated, or these transformers should be set to their default target voltages without performing any voltage increase and thus losses reduction.

NOTE: During offline analysis that determine conflicts between each level of NEM with each level of CLASS DR, tap positions of primary transformers should be presented as one of the simulation results.

9.1.4. Losses reduction simulation studies

While performing the offline analysis for NEM, it should be observed whether in some situations increase in 33 kV voltage value could bring to a loss increase. This is something that was discussed only in theory so the confirmation based on the simulations is required to see whether some changes in QUEST functionality for NEM should be introduced.

The comparison of loss reduction benefits achieved with NEM only and with CLASS DR only should be performed within the simulation studies. Based on these results it will be determined whether NEM should be switched on when CLASS is activated, or losses reduction achieved with CLASS activation is sufficient. These results will be one of the inputs for determining QUEST configuration and priorities based on which QUEST will perform coordination of different voltage techniques.

10. CONCLUSION

This document provides the description of the testing strategy needed for QUEST operational trials.

Prior focusing on the main parts of the QUEST trials, a brief overview of the agreed QUEST functionality is provided within this document.

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

After the use cases description, the testing phases timeline is provided.

Pre-production and production QUEST environment are explained afterwards. Within this section it was mentioned that additional discussions related to the testing of QUEST and external ANM systems integration during the pre-production phase should be transitioned to the next phase of the QUEST trial design.

At the end, the list of modelling studies needed to be performed by SGS prior QUEST operational trials is provided.