EcoStruxure™

QUEST Overarching Software

Lessons Learned Report

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Revision History

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1.1	Marina Klišanić	18-May-2023	Review
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Table of Contents

1. REFERENCES 6

1. ABBREVIATIONS 7

2. INTRODUCTION 8

3. QUEST LESSONS LEARNED 9

3.1. Responsive QUEST Coordination 9

3.1.1. Requirement for the current QUEST version 9

3.1.2. Lesson learned 10

3.2. Loss of communication in QUEST 10

3.2.1. Requirement for the current QUEST version 10

3.2.2. Description of the potential enhancement 10

3.2.3. Business procedure during QUEST operational trials 11

3.3. Putting Smart Street in different safe modes in case of CLASS DB enablement 11

3.3.1. Requirement for the current QUST version 11

3.3.2. Description of the potential enhancement 11

3.3.3. Business procedure during QUEST operational trials 12

3.4. Emergency SYSCON activation 13

3.4.1. Requirement for the current QUEST version 13

3.4.2. Description of the potential enhancement 13

3.4.3. Business procedure during QUEST operational trials 13

3.5. Consideration of the devices being put to local 13

3.5.1. Description of the potential enhancement 13

3.5.2. Business procedure during QUEST operational trials 14

3.6. CLASS Scheduler behaviour in case that CLASS DR is activated and the target changes (increase in requirement) 14

3.6.1. Requirement for the current QUEST version 14

3.6.2. Description of the potential enhancement 14

3.7. Terminology issues 15

3.7.1. Lesson learned 15

Table of Figures

Figure 3-1 – CLASS DB activation/deactivation and SMST 12
Figure 3-2 - QUEST Control & Monitoring – Coordinated Techniques Monitoring 15
Figure 3-3 – BSP Tap Stagger tile in QUEST Dashboard 16

Table of Tables

No table of figures entries found.

1. REFERENCES

#	Title	Description
1.	QUEST Functional Specification	Document describes final QUEST functionality agreed during design phases 1&2.
2.	QUEST Requirements	Document lists QUEST functional and non-functional requirements

1. ABBREVIATIONS

Abbreviation	Description
ANM	Active Network Management
BAU	Business as Usual
BSP	Bulk Supply Point
BSP TSF	Tap Stagger Functionality on a BSP level
CE	Control Engineer
CLASS	Customer Load Active System Services
DB	Demand Boost (CLASS Function)
DBF	Demand Boost Full (CLASS Function)
DBH	Demand Boost Half (CLASS Function)
DR	Demand Reduction (CLASS Function)
DRF	Demand Reduction Full (CLASS Function)
DRTQ	Demand Reduction Three Quarters (CLASS Function)
DRH	Demand Reduction Half (CLASS Function)
DROQ	Demand Reduction One Quarter (CLASS Function)
FAT	Factory acceptance testing
ENWL	Electricity North West Ltd.
LFDD	Low Frequency Demand Disconnection
NEM	QUEST's Network Efficiency Mode
OC6	Grid operating code 6
SMST	Smart Street
SYSCON	System Condition
TSF	Tap Stagger (CLASS Function)

2. INTRODUCTION

QUEST overarching software design has started in April 2021. From that period to the present day, QUEST overarching software has evolved from just an idea, stated through the titles of QUEST use cases, to the software application fully implemented and tested together with ENWL during FAT in QUEST simulation environment.

During QUEST design, QUEST functional requirements are introduced to capture all the agreements made during that period. Based on these agreements the final QUEST architecture option is determined and QUEST functional specification is written. QUEST functional specification was the input for QUEST development process. During the development process, QUEST test cases are written and mapped to the QUEST functional requirements. Mapping to the functional requirements is done to provide the possibility to confirm, during the QUEST testing phases, whether the agreements made during the design are fully covered within the developed QUEST functionality.

For some QUEST functional requirements, defined within that period, additional thoughts related to some future QUEST versions were added in the footnotes. The reason for mentioning the future requirements within that document was to have them listed in one place so that they can be disseminated as project 'learning'.

During QUEST FAT phase, QUEST functionalities and requirements were tested and discussed again and some of them were also marked as relevant for project 'learning'.

Lessons learned report is envisioned as the final report related to the designed and developed QUEST functionality. This report consists of the three different documents.

The first document is the final version of the QUEST Functional Specification document. QUEST functional specification is updated after the QUEST development process is finished to support the design agreements with the examples from the developed software. The purpose of providing this document within the lessons learned report is to reflect the currently implemented QUEST overarching software functionality.

The second document is the document that lists QUEST test cases, used during the QUEST FAT, together with the diagrams representing the outcome of the FAT. This document provides the information of how QUEST functionality is tested and will be tested during the upcoming testing phases, as well as the results of the first testing phase - FAT.

The third document is the lessons learned document. This document lists all the lessons learned during the previous QUEST project phases. The purpose of documenting the lessons learned is to obtain them all at one place so that they can be later used as an input when designing the BaU QUEST version. Each of the topics marked as a lesson learned can be treated as an enhancement to the currently implemented QUEST overarching software functionality potentially required for the BaU QUEST version. Some of these topics were left for the future QUEST version on purpose where for QUEST operational trials a business procedure will be defined for them, as a workaround. On the other hand, for some of the features, such as for responsive QUEST coordination, the conclusion is that currently there are physical obstacles that prevent them from being implemented. Ideas on how these features could be implemented in the future, in order to provide additional benefits through the QUEST overarching software, are provided in this document.

3. QUEST LESSONS LEARNED

This section lists all the features that could potentially be introduced in the QUEST BaU version. These features are marked as lessons learned since they are created based on the discussions held during the QUEST design and testing phases. Conclusion for all these features is that they are not necessarily needed for the QUEST operational trials since during the trials appropriate business procedures can be created as a workaround. For QUEST BaU version, these features will be discussed again and used as the starting point during the design.

For each lesson learned, the QUEST functional requirement for the current QUEST version is stated first. It is then followed by the appropriate business procedure that will be defined for it during QUEST operational trials, if applicable. After that, the requirement for the QUEST BaU version is provided, if applicable, or a lesson learned is described. Functional requirements are taken from the QUEST requirements document.

3.1. Responsive QUEST Coordination

3.1.1. Requirement for the current QUEST version

13.	QUEST configuration is to provide the possibility to define the type of coordination performed by QUEST. It is to be possible to define whether QUEST coordination will be **Proactive** or **Responsive**.
14.2	In case of **Responsive** coordination type, priorities and desired function levels are not to be configurable. In this case, the priorities are to be as follows: 1. CLASS DR 2. SMST 3. NEM 4. BST TSF, where the priority is set in descending order, from CLASS to BSP TSF. The function levels are to be as follows: - CLASS DR 100% - CLASS DB 0% - SMST 100% NEM 100%
20.	**Responsive** coordination type is to be introduced in QUEST in order to test and trial fast tap capability of Smart Street transformers for coordination of Smart Street with CLASS. Fast tap capability should be used in order to leverage coordination of Smart Street and CLASS with Smart Street being put into a safe mode upon CLASS functions activation (DR), rather than CLASS functions enablement. This approach would introduce additional flexibility to the QUEST overarching software since it will provide the

	possibility to fully maintain customer benefits from Smart Street CVR during the whole period of CLASS functions enablement.

3.1.2. Lesson learned

During QUEST design, it has been confirmed that fast tap capability of SMST transformers does not presently satisfy requirements defined for the QUEST responsive coordination type. Bearing that in mind, it has been agreed that the responsive coordination type will only be shown on QUEST's UI and no additional logic behind this option will be implemented within the current QUEST version. This decision is made to allow possibility to present the concept and conclusions made during the QUEST design, as well as a reminder for the future QUEST development. Although responsive coordination type is not implemented in the current QUEST version, description of this functionality and how it is envisioned within QUEST is described in the QUEST functional specification document, as a reminder for the future QUEST versions.

3.2. Loss of communication in QUEST

3.2.1. Requirement for the current QUEST version

29.1	In case of situation where communication with CLASS primary substations is of good quality, but the communication with SMST transformers has been lost, QUEST is to automatically intervene. QUEST is to disable/inhibit CLASS on all primary substations supplying SMST transformers with the lost SCADA communication and try to compensate for the provision of services by enabling CLASS on other primary substations that do not supply SMST transformers, if such exist. Additionally, the QUEST CE is to be notified that QUEST automatically intervened due to a loss of communication with the SMST transformers by reporting an appropriate alarm message.

3.2.2. Description of the potential enhancement

During the FAT, this feature has been discussed additionally to determine whether there are some options to enhance it. The issue with this logic is that in case of loss of communications to only one SMST transformer, CLASS functions on a primary supplying that SMST transformer get inhibited by QUEST and the whole area supplied from that CLASS primary loses CLASS benefits. It is expected that these situations could happen often meaning that provision of CLASS benefits could be affected significantly.

Potential enhancement is introducing the logic of a SuperTapp SG Relay on BSP transformers to SMST controllers (tap to failsafe target voltage in case of loss of communications). In that case, there would be no need to inhibit CLASS because of one SMST transformer with lost SCADA communication. CLASS would be able to operate on that area. If enhancing the SMST transformers' controller is feasible, then QUEST could be enhanced not to inhibit CLASS primaries in case of loss of communication with SMST transformers. This is yet to be investigated. The current logic in the SMST controller does not have the logic of defaulting to the default voltage set point in case of loss of communication, but the next generation may have that possibility.

NOTE: This proposal resolves only one issue - causing LV violations in case of CLASS activation. The other issue is that, although SMST controller taps to its default target voltage in case of loss of communication, it continues maintaining that voltage. In case of CLASS DR activation, once voltage reduction is performed, SMST controller would react on that event, to return the voltage values in its defined range, thus conflicting the provision of CLASS benefits. This situation is still to be discussed for the BaU QUEST version.

3.2.3. Business procedure during QUEST operational trials

It was agreed during QUEST FAT that the current QUEST behaviour is acceptable for QUEST operational trials. For BaU QUEST version this should be discussed additionally.

3.3. Putting Smart Street in different safe modes in case of CLASS DB enablement

3.3.1. Requirement for the current QUEST version

8.3.4	QUEST scheduling mechanism is to be able to decide which levels of demand boost (demand boost full (DBF) or demand boost half (DBH)) should be enabled per CLASS primary substation in order to satisfy CLASS committed targets, but also to minimise the impact of CLASS on other voltage control techniques i.e. trying to gain as much benefits as possible from all the voltage control techniques that it coordinates.

Depending on the level of CLASS DR/DB, the allowed levels of SMST LV efficiency are determined. These allowed levels of SMST LV efficiency are defined as safe modes for SMST. Proactive coordination is performed in the case of SMST and CLASS coordination since QUEST is not able to determine when CLASS services will be needed and when CLASS will be activated by ESO. Due to this fact, QUEST is not able to perform the coordination actions prior to CLASS being activated.

Based on the CLASS DB levels supported through the SuperTAPP Relay on CLASS primary substations, 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 DBH deactivation.
- **100% of LV efficiency –** this percentage 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 functions enabled.

3.3.2. Description of the potential enhancement

During the design, it was concluded that for each DB level, appropriate SMST safe mode should be introduced. After discussing this feature on QUEST FAT, it is concluded that it is not necessary to have multiple safe modes and that only one SMST DB safe mode should exist. The only thing that is important is to fix SMST transformer tap position in order not to have SMST local controller conflicting provision of CLASS benefits upon CLASS DB activation. Regardless of the level of CLASS DB, if SMST transformer is on a fixed tap position, upon CLASS DB activation, voltage will be increased for a desired value (3% or 5% demand boost). Upon CLASS DB deactivation, voltage values will be decreased for that same amount meaning that the voltage values will end up on approximately same value they were prior DB activation (natural change in load should also be considered). Bearing this in mind, there is no need to introduce different predefined voltages for different levels of CLASS DB. SMST transformers could be put in a safe mode that allows maximum level of LV efficiency (SMST function level 75% used for coordination with CLASS DR). If put on a target voltage e.g. 92% of the nominal voltage (240V) and with fixed tap position during CLASS DB enablement (both DBF (5% voltage increase) and DBH (3% voltage increase)), upon CLASS activation, voltage value will be increased from 92% to approximately 95% or 97%), and decreased for that same value upon deactivation, which means that there will be no voltage violations upon deactivation. This is shown in Figure 3-1.

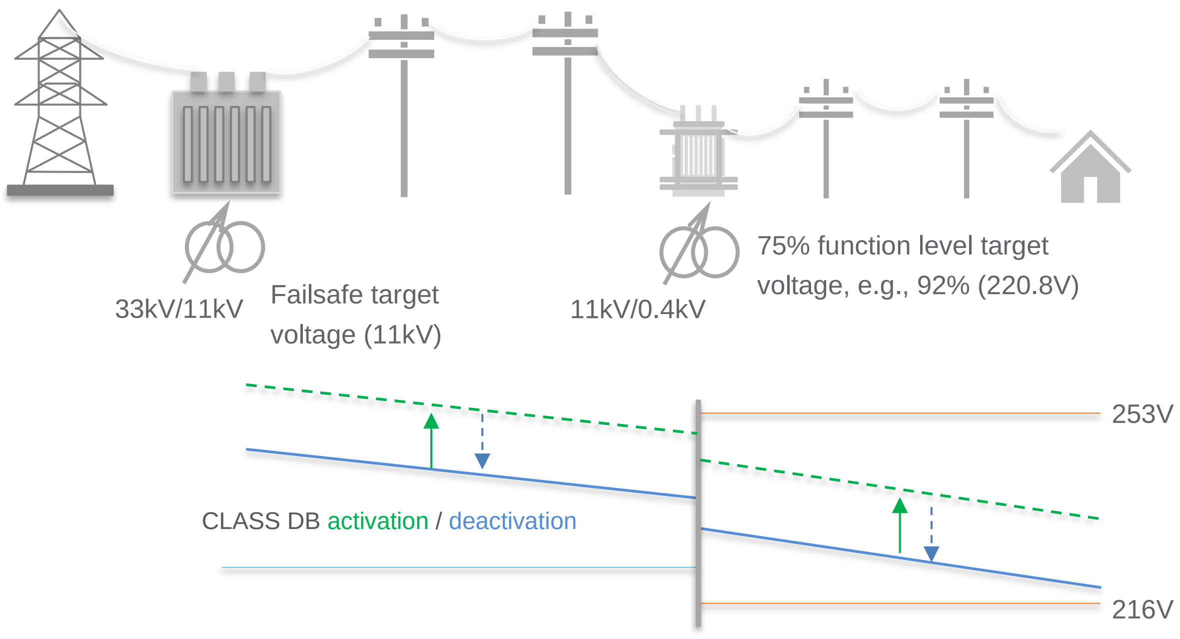


Figure 3-1 – CLASS DB activation/deactivation and SMST

3.3.3. Business procedure during QUEST operational trials

It was agreed that, for operational trials, changes are not needed in QUEST logic. The business procedure will be to adjust the QUEST predefined target voltages for SMST DB safe modes to a same value (value defined for 75% SMST function level). For BaU QUEST version this should be discussed additionally and determine whether only one safe mode should be introduced for CLASS DB coordination with SMST.

3.4. Emergency SYSCON activation

3.4.1. Requirement for the current QUEST version

10.1	The specifically authorised Control Room personnel are to have the possibility to set the following emergency SYSCON: SYSCON-1 = System Recovery [Black Start] State (Grid Code OC9), SYSCON-2 = LFDD Automatic Activation State (Grid Code OC6.6), SYSCON-3 = LFDD Manual Activation State (Grid Code OC6.7), SYSCON-4 = OC6 stages 3 to 5 State (Grid Code OC6.5, Demand Disconnections), SYSCON-5 = OC6 stages 1 & 2 State (Grid Code OC6.5, 3% & 6% Voltage Reductions), and to return QUEST into normal operation mode SYSCON-6 after the emergency condition passes.

3.4.2. Description of the potential enhancement

As per QUEST design, all emergency SYSCONs, except auto LFDD, are manually activated.

It was discussed whether QUEST BaU should be enhanced to automatically detect emergency condition, as it is the case with the auto LFDD, and perform all the steps to set voltage control techniques in appropriate mitigation modes. This will decrease the number of manual operations for the QUEST CE, as well as prevent from introducing the human error in case of emergency system conditions.

3.4.3. Business procedure during QUEST operational trials

It will be a business procedure to manually start the SYSCON-5, SYSCON-4 and SYSCON-3 as one of the actions for preparing for the actual OC6-VR, OC6-DD and LFDD.

3.5. Consideration of the devices being put to local

As per agreements made during the design, QUEST is not made aware of BSP or SMST transformers being put to local mode of operation. QUEST does not consider Local signals on these transformers since that was treated as a requirement for BaU QUEST version during the design.

3.5.1. Description of the potential enhancement

During FAT it was discussed whether this functionality is needed for the operational trials, as well. The reason for this is the fact that during the live trials, it could happen that a particular SMST transformer or BSP transformer is put in a local mode. If QUEST does not consider this information in its calculation, it could end up sending commands to those devices, which is not acceptable.

The conclusion is made that for operational trials, a change in QUEST software is not needed, since a business procedure can be defined as a work around. For BaU version, QUEST should be aware of devices put to local state.

3.5.2. Business procedure during QUEST operational trials

Business procedure will be to perform additional actions if a device is put to local:

- For SMST transformers procedure will be to deenergize SMST transformer upon putting it to local (if deenergized, QUEST does not consider it). This is only in case that reason for putting it to local is de energisation. If the SMST transformer is to remain live, it will only be put in local, because it cannot be shown as deenergised. It will be additionally discussed whether some additional actions should be performed in this situation.
- For NEM, procedure will be to put BSP substation, whose transformers are put to local, to Blocked state in QUEST Control and Monitoring.

3.6. CLASS Scheduler behaviour in case that CLASS DR is activated and the target changes (increase in requirement)

3.6.1. Requirement for the current QUEST version

8.3.1	Scheduling mechanism introduced through QUEST (QUEST scheduling mechanism) is to automatically enable CLASS functions on a number of CLASS primaries in order to satisfy CLASS committed targets.
8.3.2	QUEST scheduling mechanism is to be able to decide which levels of demand reduction (DRF, DRTQ, DRH or DROQ) should be enabled per CLASS primaries in order to satisfy CLASS committed targets, but also to minimise the impact of CLASS on other voltage control techniques i.e., trying to gain as much benefits as possible from all the voltage control techniques that it coordinates.

During the design, it was discussed how CLASS scheduling mechanism could be enhanced within QUEST and what should be the logic in QUEST in order to determine the optimum balance between CLASS enabled primary substations and other voltage techniques adjustment.

3.6.2. Description of the potential enhancement

During the QUEST FAT, a question was asked about QUEST's behaviour in case CLASS DR gets activated and CLASS committed target increases during its activation period.

During the design, only scenarios where QUEST prepares CLASS for its activation period, were discussed, and no additional logic is introduced for situations where it is expected to compensate for the shortfalls in case of changed target during the activation period.

It was agreed that for operational trials, QUEST behaviour should at least be aligned with the CLASS scheduling mechanism in this situation.

ENWL confirmed post-FAT that CLASS scheduling mechanism behaves as follows:

"When Class sites are activated, the scheduler does not recalculate for the change in requirement at ½ hr period. As soon as the Activation is deactivated, the scheduler immediately recalculates for the new target."

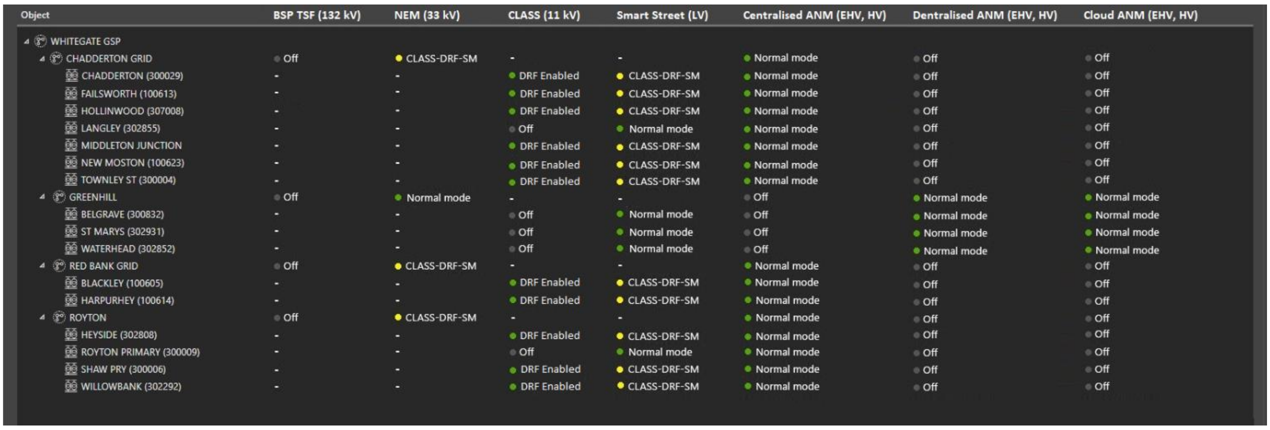
Bearing that in mind, the conclusion is that for operational trials, QUEST behaviour does not need to change. For BaU QUEST version, this scenario will be additionally discussed, and an enhancement of current QUEST functionality will be determined.

3.7. Terminology issues

3.7.1. Lesson learned

One of the conclusions made during QUEST FAT is that terminology used within QUEST overarching software is not completely aligned with the rest of the applications within NMS software. It was explained that QUEST Control & Monitoring window is different than the Closed loop management windows of the other voltage control techniques since the nature of QUEST is different. Other voltage control techniques have their own objectives such as CVR, in case of SMST, thermal protection of the assets, in case of ANM. These applications can be configured either to perform their objectives, when they are enabled, or not, when they are disabled. QUEST's objective is to coordinate other voltage control techniques and constraint management applications existing in ENWL network. Thus, statuses of these applications in QUEST monitoring section are presented from the perspective of QUEST operation.

If application is disabled, or in test, inhibited, or blocked state, from perspective of QUEST that means that application is not operating on the affected part of the network and does not have to be coordinated by QUEST. Thus, it is displayed as in Off state that uniquely represents all above-mentioned states. On the other hand, if application coordinated by QUEST is enabled, that means that QUEST should either intervene in its operation and put it in appropriate safe mode or should leave it in its normal mode of operation. Because of that, there is no Enabled status in QUEST Control & Monitoring, but the Normal mode of operation status or appropriate safe mode, as can be seen in Figure 3-2.



Object	BSP TSF (132 kV)	NEM (33 kV)	CLASS (11 kV)	Smart Street (LV)	Centralised ANM (EHV, HV)	Dentralised ANM (EHV, HV)	Cloud ANM (EHV, HV)
WHITEGATE GSP							
CHADDERTON GRID	Off	CLASS-DRF-SM	-	-	Normal mode	Off	Off
CHADDERTON (300029)	-	-	DRF Enabled	CLASS-DRF-SM	Normal mode	Off	Off
FAILSWORTH (100613)	-	-	DRF Enabled	CLASS-DRF-SM	Normal mode	Off	Off
HOLLINWOOD (307008)	-	-	DRF Enabled	CLASS-DRF-SM	Normal mode	Off	Off
LANGLEY (302855)	-	-	Off	Normal mode	Normal mode	Off	Off
MIDDLETON JUNCTION	-	-	DRF Enabled	CLASS-DRF-SM	Normal mode	Off	Off
NEW MOSTON (100623)	-	-	DRF Enabled	CLASS-DRF-SM	Normal mode	Off	Off
TOWNLEY ST (300004)	-	-	DRF Enabled	CLASS-DRF-SM	Normal mode	Off	Off
GREENHILL	Off	Normal mode	-	-	Off	Normal mode	Normal mode
BELGRAVE (300832)	-	-	Off	Normal mode	Off	Normal mode	Normal mode
ST MARYS (302931)	-	-	Off	Normal mode	Off	Normal mode	Normal mode
WATERHEAD (302852)	-	-	Off	Normal mode	Off	Normal mode	Normal mode
RED BANK GRID	Off	CLASS-DRF-SM	-	-	Normal mode	Off	Off
BLACKLEY (100605)	-	-	DRF Enabled	CLASS-DRF-SM	Normal mode	Off	Off
HARPURHEY (100614)	-	-	DRF Enabled	CLASS-DRF-SM	Normal mode	Off	Off
ROYTON	Off	CLASS-DRF-SM	-	-	Normal mode	Off	Off
HEYSIDE (302808)	-	-	DRF Enabled	CLASS-DRF-SM	Normal mode	Off	Off
ROYTON PRIMARY (300009)	-	-	Off	Normal mode	Normal mode	Off	Off
SHAW PRY (300006)	-	-	DRF Enabled	CLASS-DRF-SM	Normal mode	Off	Off
WILLOWBANK (302292)	-	-	DRF Enabled	CLASS-DRF-SM	Normal mode	Off	Off

Figure 3-2 - QUEST Control & Monitoring – Coordinated Techniques Monitoring

Another topic that was discussed is the QUEST PROFILE Editor window. QUEST PROFILE Editor differs from PROFILEs of other applications. It introduces new logic of saving and editing the configuration. It has both Save and Save As buttons which are not common in the rest of the software and is deemed as confusing to the operators.

The agreement is made that for operational trials, the logic will not be changed, and it is important that is only explained well to the control engineers. For BaU QUEST version, it will be discussed which of these features should be aligned with the rest of the software, and for which ones it is reasonable to be different.

Another topic for QUEST BaU version discussion is BSP Tap Stagger tile in QUEST Dashboard, shown in Figure 3-3.

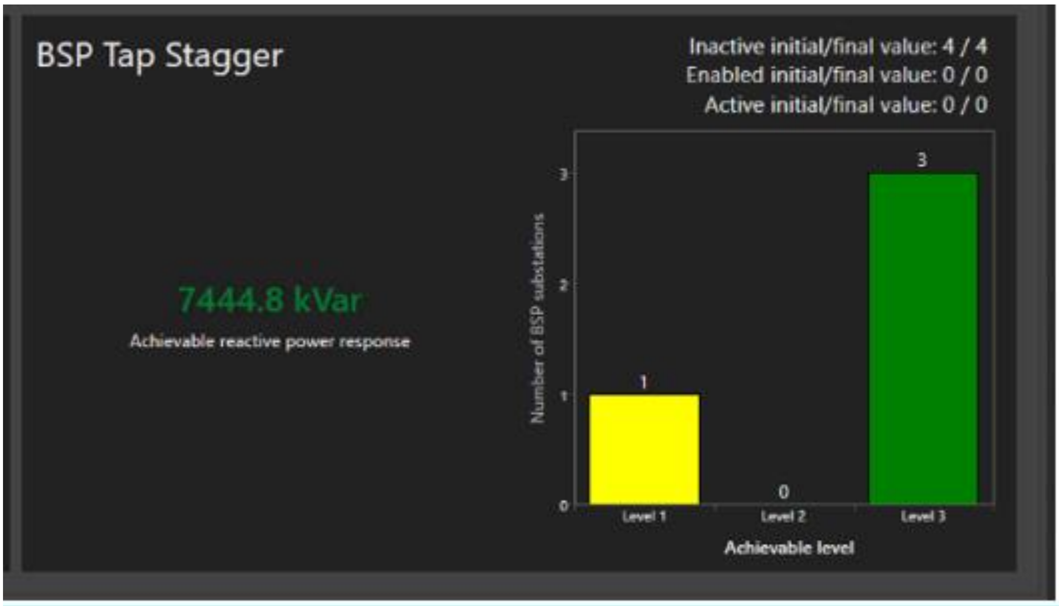


Figure 3-3 – BSP Tap Stagger tile in QUEST Dashboard

Initial and final BSP TSF statuses displayed in the upper right corner of the BSP TST tile in QUEST Dashboard are also discussed. The question is whether this information is presented in the best format, whether it is confusing or should it be displayed at all. It should be discussed to whom this information is of interest and where it should be presented, if needed.

The agreement is that for operational trials, the tile should not be changed, but should be mentioned in the lessons learned report as a reminder for the BaU QUEST version discussions.