Resilience as a Service

Scottish & Southern Electricity Networks

Trial Testing, Installation & Commissioning Plan and Budgetary Cost Estimate

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1. DOCUMENT ISSUE CONTROL

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CONTENTS

TABLES

FIGURES

2. INTRODUCTION

2.1. Project Background

Scottish Hydro Electric Power Distribution (SHEPD) has contracted Smarter Grid Solutions (SGS) to support Scottish & Southern Electricity Networks (SSEN) on SSEN Work Package 3 (SWP3) 'Detailed DNO Scheme Design' within Phase 1 of their Resilience as a Service (RaaS) innovation project.

This Network Innovation Competition funded project aims to improve energy security in rural and remote areas by combining battery storage with local energy resources to provide low carbon, cost effective network resilience in response to faults. The project is being delivered by three project partners - SSEN as the network operator together with smart infrastructure experts Costain and leading European energy company E.ON.

SWP3 requires SGS to produce a detailed DNO scheme design for the project's selected trial site[1], which also considers replicability across further sites. The DNO scheme design comprises the system architecture for the DNO side aspects of the RaaS system, including its integration with existing SSEN assets and interface with the external (third party owned) elements of the RaaS scheme (under development by E.ON), together with the supporting DNO side operational functions, control processes and information exchanges required to implement a RaaS solution. SGS will be required to engage with SSEN and their partners throughout SWP3.

This 'DNO RaaS Controller Trial Testing, Installation and Commissioning Plan and Budgetary Costs Estimate' report builds on the 'DNO RaaS Controller Detailed Design Specification' and the 'DNO RaaS Controller Requirements & Use Case Specification' reports.

2.2. SWP3 - Detailed DNO Control Scheme Design for the Selected Trial Site

SGS's proposal for SWP3 takes SSEN's 24 required Scope of Works (SoW) items (see Appendix 1) and addresses these through a smaller number of logically cognate and sequential tasks that incorporate the complexity and interdependency across these areas. This brings together the diverse domains across the common themes of requirements specification, Use Case specification, architecture modelling as well as detailed technical and procedural design. Organising the project in this way also enables clear and efficient project management. SGS has mapped the 24 SSEN SoW items to six tasks, with four milestone deliverable documents, as set out in Schedule 1 of the agreed SHEPD/SGS Contract [1].

The Tasks are as follows:

Task 1	Initiation, Review of Project Progress, Project Outputs and Liaison with partners
Task 2	DNO RaaS Controller Requirements and Use Case Specification
Task 3	DNO RaaS Controller Architecture Specification
Task 4	DNO RaaS Controller Detailed Design Specification
Task 5	DNO RaaS Controller Testing, Installation, Commissioning and Trial Plan
Task 6	DNO RaaS Controller Design Delivery Reporting and Supporting Dissemination

[1] SSEN are specifying the works and equipment to replace the existing 11kV switchboard at the Drynoch primary substation trial site with a new suitable 11kV switchboard for the RaaS trial.

The agreed milestone deliverables are:

SWP3-1	DNO RaaS Controller Requirements and Use Case Specification document, Tasks 1 & 2
SWP3-2	DNO RaaS Controller Detailed Design Specification document, Tasks 3 & 4
SWP3-3	DNO RaaS Controller Trial Testing, Installation and Commissioning Plan and Budgetary Cost Estimate, Task 5
SWP3-4	SWP3 DNO RaaS Controller Project Summary Report, Task 6

2.3. Task 1 - Initiation, Review of Project Progress, Project Outputs and Liaison with Partners

Task 1 comprised initiation of SWP3 with familiarisation of existing project material and information available from SSEN, together with ongoing liaison with SSEN and other RaaS project partners, as necessary. This included an extensive peer review and feedback on the E.ON RaaS Front End Engineering Design (FEED) report [2].

2.4. Task 2 - DNO RaaS Controller Requirements and Use Case Specification

Task 2 involved capturing, analysing and specifying the following to enable the detailed design to address all functional, system, user, information and other requirements:

- High-level functional requirements.
- Functional use cases.
- Detailed requirements (functional, non-functional, roles/responsibility, infrastructure & security).

Task 2 is documented in [3] and covers items 2, 4, 5, 6, 8, 9, 12 and 15 from the SSEN Scope of Work for SWP3: along with the outputs of Task 1, items 1, 19, 20, 21 and 22.

2.5. Task 3 - DNO RaaS Controller Architecture Specification

Task 3 defined the appropriate DNO RaaS Controller system architecture that will deliver the use cases and meet the requirements captured based upon logical requirements.

The architecture developed in collaboration with SSEN incorporates communications infrastructure protocols and, data transfers, and captures the distinctions between different hosting environments e.g. SSEN IT, OT and RTS systems, third-party/non-SSEN, and project partner/RaaS Service Provider components of the overall solution, at an appropriate level of detail.

Where distinction exists, the architecture presents features that are specific to the innovation project trial, and those that may be established for BaU roll-out.

Task 3 is documented in [4] covers items 3, 4, 6, 7, 11 and 13 from the SSEN Scope of Work for SWP 3 along with the outputs of Task 2 above.

The outputs from Task 3 feed directly into and are a core part of Task 4 below.

2.6. Task 4 - DNO RaaS System Detailed Design Specification

The detailed design has been developed based on the generic DNO RaaS Controller Requirement Specification (Task 2). In line with the approach taken for the requirements specification and architecture specification (Task 3), the detailed design identifies any relevant distinctions between the design for a vendor agnostic general case and features relating to the trial system planned for Drynoch Primary substation.

The Detailed Design Specification (DDS) covers the following:

- RaaS control solution overall design and embedded operating principles and procedures.
- Functional control logic capturing the following operating modes:
  - grid connected operation.
  - grid-connected to islanded transition.
  - island operation (including DER embedded within the network).
  - island-to-grid synchronisation and transition.
  - black start.
- Communications media, information standards and protocols.
- Network monitoring, visibility and operator intervention - including alarms to the DNO DMS (Distribution Management System) and associated interface design of required functionality within SCADA and the central DMS.
- Fail-safes and communication reliability issues.
- Third-party RaaS control interfaces.
- Operational risks and mitigation measures.
- Cyber Security: risks and security design.
- Organisational models.

Task 4 is documented in [4] and includes items 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 20, and 21 from the SSEN Scope of Work along with the outputs of Tasks 2 and 3 above.

2.7. Task 5 - DNO RaaS System Testing, Installation, Commissioning and Trial Plan

In Task 5, we define an implementation plan to support planning the network trial stage of the project including:

- **Test Programme**: detailing the programme of tests that are required to validate design functionality. This will present the key test elements required and the different test stages to be executed.
- **Commissioning and implementation plan**: based on the system components, functionality, SAT (in situ) and trial operation period requirements.
- **Trial implementation cost estimation**: provide a budgetary estimate for DNO RaaS control system implementation and testing.

Task 5 includes items 16, 17 and 18 from the SSEN Scope of Work.

2.8. Task 6 - DNO RaaS Controller Project Summary Report

The delivery of the detailed design methodology in Tasks 1 to 5 are to be captured in a summary report.

The summary report will provide material for dissemination support to SSEN, in keeping with the requirements of NIC governance and accepted/standard approaches and sub-contractor roles in dissemination.

SGS will further support the dissemination of SWP 3 findings through contribution to supporting materials for workshop, webinar or conference presentation, including supporting the delivery of such events with industry-recognised subject-matter experts from the SGS team.

This task includes items 23 and 24 from the SSEN Scope of Work.

2.9. Scope

This document builds on the Tasks 2, 3 and 4 and covers:

- Task 5 - DNO RaaS Controller Testing, Installation and Commissioning Plan and Budgetary Cost Estimate.

This document forms the SWP3-3 deliverable.

2.10. Exclusions

Task 5 does not cover the following topics:

- Changes to SSEN's DMS other than new alerts/status updates and control commands necessary for the Control Room to have visibility of the RaaS scheme and interact with the DNO RaaS Controller which form part of the testing plan.
- Detailed functionality of third-party systems (e.g. the BESS EMS, protection schemes, measurement and automation) other than functions relevant to the DNO RaaS Controller testing plan.
- SSEN's communications infrastructure other than details relevant to the DNO RaaS Controller.
- SSEN's processes (including backup processes).
- SSEN's policies.

2.11. Document Structure

The remainder of this document is structured as follows:

Section 3	DNO RaaS Controller Test Programme.
Section 4	DNO RaaS Controller Installation and Commissioning Programme.
Section 5	DNO RaaS Controller Cost assumptions for Procurement and Installation.
Appendix 1	Appendix containing SSEN SWP3 scope of work

2.12. Intended Audience

The intended audience is as follows:

- SGS Project Design Team.
- SSEN RaaS Delivery Team.
- SSEN BaU teams including Design, OT, RTS and the Control Room.
- E.ON RaaS Design Team.
- Costain RaaS Team.
- Potential suppliers of RaaS equipment, including those who may tender to provide the DNO RaaS Controller.
- Other DNOs, and those with an interest in the development of enhanced flexible solutions.

2.13. Stakeholders

Table 1 lists the various stakeholders and their interests in the project.

Table 1 - Stakeholders

Stakeholder	Interest
SGS	Consultant appointed to develop the DNO RaaS Controller requirements, design, and testing specifications.
SSEN	DNO appointed to deliver the RaaS project, including development of the DNO side system to interface with the external RaaS BESS, and in the context of creating a scheme suitable for future business as usual role out of RaaS.
SSEN - including Design, OT, RTS, Control Room	Approval of designs & equipment prior to implementation of a RaaS scheme, interaction with the ongoing operation of RaaS. Approval of the testing of the system functions/architecture, user interface and review of the various test plan results. Party to the DNO RaaS Controller pre-production and site acceptance testing. BaU system approvals and operations of BaU systems.
E.ON - RaaS	Technical development of the RaaS BESS system and associated Energy Management System, and its interfacing with SSEN assets. Party to the DNO RaaS Controller pre-production and site acceptance testing.
Costain - RaaS	Appraising the supply chain for RaaS, though stakeholder engagement with those who may participate in delivering a RaaS solution.
Equipment Suppliers	Those who may provide equipment or services necessary for the implementation and testing of a RaaS scheme.

2.14. Reference Documents

This report refers to the following documents associated with the RaaS project and the DSO Controller element requirements.

[1] Research and Development agreement between Scottish Hydro Electric Power Distribution Plc and Smarter Gris Solutions Ltd "Project; FW Services - RaaS Phase 1 Project Support - Multisite 0721 Purchase Order number; 1221060522", dated 06/01/2021.

[2] Resilience as a Service 'Front End Engineering Design (FEED)' report, version v2.0, dated 17/02/2021.

[3] Smarter Grid Solutions report "Resilience as a Service, DNO RaaS Controller Requirements and Use Case Specification", Document No. 200993 03 version C, 13/05/2021.

[4] Smarter Grid Solutions report "Resilience as a Service, DNO RaaS Controller Detailed Design Specification", Document No. 200993 04 version B, 18/05/2021.

2.15. Terminology

Table 2 describes acronyms and other terms used within this document.

Table 2 - Terminology

Term	Definition
ANM	Active Network Management
ATS	Acceptance Test Specification
BaU	Business as Usual - refers to business as usual deployment of RaaS following successful trials
BESS	Battery Energy Storage System
CB	Circuit Breaker
CT	Current Transformer
DAR	Delayed Auto Reclosers
DDS	Detailed Design Specification
DER	Distributed Energy Resource
DERMS	Distributed Energy Resources Management System
DG	Distributed Generation
DMS	Distribution Management System
DNP3	Digital Network Protocol 3
DNO	Distribution Network Operator
EMS	Energy Management System

Term	Definition
FEED	Front End Engineering Design
HiL	Hardware in the Loop testing.
LOM	Loss of Mains
OT	Operational Technology
PMCB	Pole Mounted Circuit Breaker
PPT	Pre-Production Acceptance Testing
PQM	Power Quality Monitoring
RaaS	Resilience as a Service
RTS	Real Time Systems
RTU	Remote Terminal Unit
SAT	Site Acceptance Testing
SCADA	Supervisory Control and Data Acquisition
SGS	Smarter Grid Solutions
SSEN	Scottish and Southern Electricity Networks
TCP/IP	Transmission Control Protocol of the Internet Protocol suite
Threshold	Setting at a Measurement Point
UI	User Interface
VT	Voltage Transformer

3. DNO RAAS CONTROLLER TEST PROGRAMME

Section 3 sets out a schedule of tests for the DNO side aspects of the RaaS system (DNO RaaS Controller) which aim to demonstrate its integration with existing SSEN assets and its interfaces with the external elements of the RaaS system. This is a staged approached that will progress from factory testing to site acceptance testing, incorporating all elements involved in the overall RaaS scheme.

Site acceptance testing (SAT) should be coordinated by SSEN with other parties including the RaaS BESS/BESS EMS provider for the project, E.ON, and relevant parties within SSEN including the OT (Operational Technology), RTS (Real Time Systems) and Control Room teams. To support this coordination, indicative timescales covering the installation and commissioning programme proposed for the project trial scheme are provided in section 4 - note that these timescales will ultimately depend on agreement with the appointed DNO RaaS Controller vendor, E.ON as project partner responsible for the BESS scheme, and other parties within SSEN.

The test programme is focussed on testing the DNO RaaS Controller functionality, other elements forming the overall RaaS scheme e.g. the BESS, BESS EMS, BESS transformer/earthing arrangement, synchronising breaker/loss of mains detection system will have their own individual test plans. The DNO RaaS Controller test programme does include the interaction with the other RaaS elements either in simulation during Factory Acceptance Testing (FAT), or with full integration during SAT and elements of integration and simulation during Pre-production Testing (PPT). Fault ride through associated with distribution network short or open circuits is not considered for the DNO RaaS Controller test programme as loss of mains detection and associated opening of the synchronising circuit breaker is not part of the DNO RaaS Controller functionality, this is provided by other elements of the overall RaaS scheme. The DNO RaaS Controller functionality detects and responds to change in the synchronising circuit breaker status and other monitored parameters to determine transition from grid operations to either island or blackout conditions. All DNO RaaS Controller functional use cases are tested as part of the test programme set out in this section.

3.1. Test Stages

The DNO RaaS Controller Acceptance Test Specification (ATS) should apply three stages of testing, namely Factory Acceptance Testing (FAT), Pre-Production Acceptance Testing (PPT) and Site Acceptance Testing (SAT). It is not necessary to carry out every test identified within this report during all test stages. The description of each test (see section 3.3) includes an indication of the test stages where each test is applicable. Where necessary, subject to results from the FAT, there is a potential option for additional testing at a specialist test facility such as PNDC[2] prior to SAT. The need for this option and the details of any such testing would be developed by the RaaS Scheme partners and the appointed DNO RaaS Controller supplier based on the findings from prior testing activities, with the intention to mitigate potential risks associated with the application of RaaS.

[2] The Power Networks Demonstration Centre is a venture founded by government, industrial and academic partners with the aim of accelerating the adoption of innovative research and technologies from early stage research into business as usual adoption by the electricity industry.

3.2. Test Environments

FAT is to be performed on the DNO RaaS Controller vendor's premises and overseen by SSEN representatives. This tests all functional and non-functional elements of each sub-system component and the system as a whole.

Following the successful completion of FAT and subject to any identified testing at a specialist testing facility, the DNO RaaS Controller will be established and integrated within the SSEN test environment laboratory, and the BESS EMS vendor premises and subjected to the PPT testing described in this document. This will include hardware in the loop (HiL) testing elements at both these locations, as described later in this section.

3.2.1. FAT Environment

Figure 1 shows the system architecture environment that should be adopted for FAT. Where the target external systems are not available, the interfaces are to be appropriately simulated to test the required functionality.

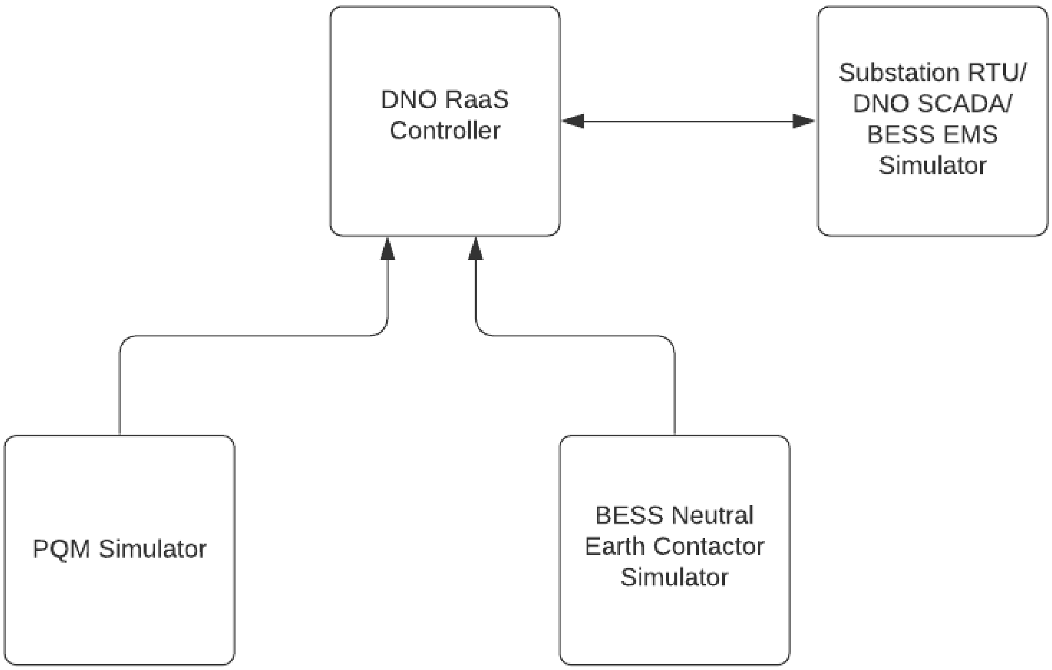

Figure 1 - FAT Environment

3.2.1.1. Simulated Components

- Substation RTU Simulator - The Substation RTU Simulator must be designed to simulate messages/responses to the DNO RaaS Controller for all communications with the Substation RTU as well as simulating the messages and responses that would be sent to and from the Substation RTU from the DNO SCADA and BESS EMS.
- PQM Simulator - The PQM simulator must provide the simulated frequency, voltage and power measurements to the DNO RaaS Controller. As an alternative to using a software programme, simulated analogue/digital measurements from the CT/VTs to the DNO RaaS Controller PQM could also be applied using a secondary test injection set to replicate signals from the substation environment, however this may incur additional cost.

- RaaS BESS transformer neutral earth contactor Simulator - This must simulate a signal agreed upon between the DNO RaaS Controller vendor and SSEN (e.g. 110VDC) to be sent to the DNO RaaS Controller to mimic the RaaS BESS transformer neutral earth contactor.

3.2.1.2. Software

All DNO RaaS Controller software required for full functionality, including third party software, must be installed and logged prior to FAT.

3.2.1.3. FAT Simulation

A key part of FAT is simulation. This is intended to mimic the real-life signals and conditions to the DNO RaaS Controller as close as practicably possible. The signals to be simulated are as follows:

- All messages sent between the DNO RaaS Controller and Substation RTU.
- All required measurements from the PQM including voltage, frequency and power.
- The status of the RaaS BESS transformer neutral earth contactor.

Simulation platforms can be programmed to automatically or/or manually send messages (e.g. status signals, alerts, alarms) to the DNO RaaS Controller in order to mimic the real equipment, and similarly programmed to react to signals and messages sent from the DNO RaaS Controller.

The responses of the system will be logged for review to validate testing or identify areas for rectification.

3.2.2. Specialist Testing Facility

Depending on the results from the FAT, the requirement for additional testing at a specialist test facility (such as PNDC) may be identified to provide further confidence that risks will be minimised during SAT. The need for and details of any such testing will be developed following FAT by the RaaS project partners in collaboration with the appointed DNO RaaS Controller supplier.

3.2.3. Pre-Production Testing (PPT) Environment

PPT has two aspects:

1. Testing on SSEN premises within SSEN's test environment.
2. At the BESS factory/supplier premises when integrated with the BESS EMS during the BESS EMS FAT (if time/budget allows).

3.2.4. PPT (SSEN Test Environment).

Within the SSEN test environment, the DNO RaaS Controller must be integrated with SSEN's test RTU and test DNO SCADA system, with a simulated BESS EMS used. This hardware in the loop (HiL) test environment is shown in Figure 2.

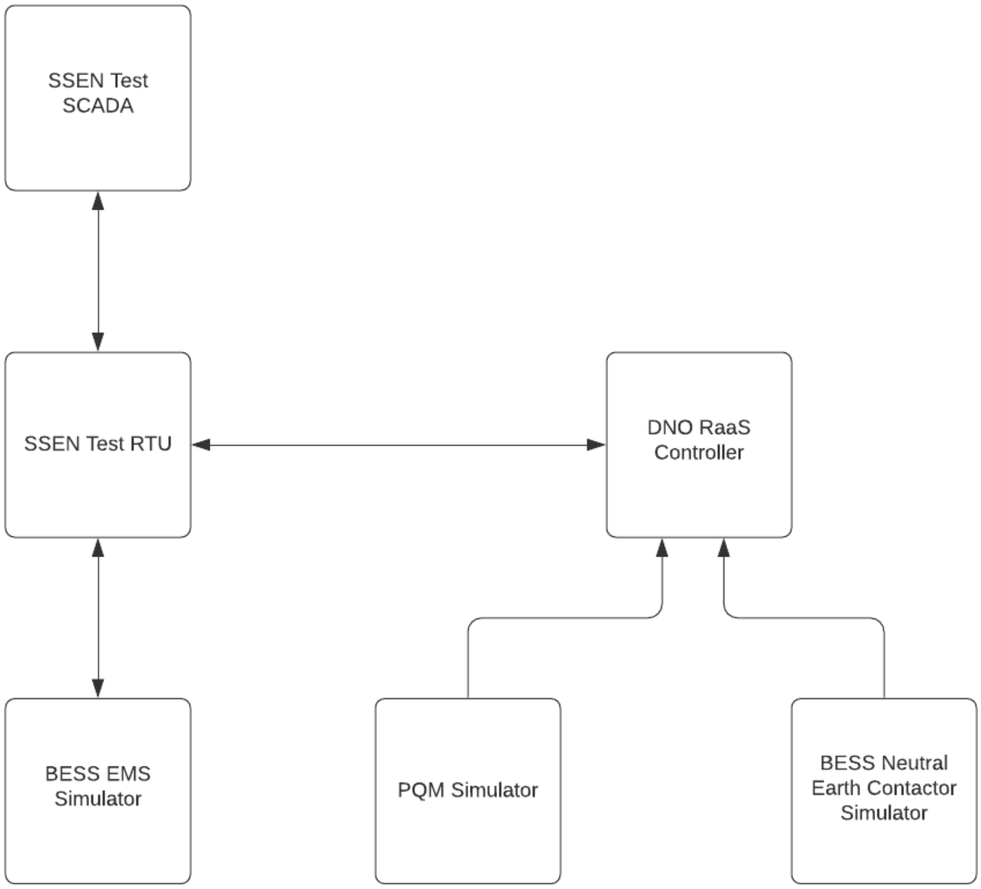

Figure 2 - PPT Environment: SSEN Test Laboratory Premises

3.2.4.1. Software

All software and specific versions of software used on the DNO RaaS Controller logged prior to FAT must be installed and logged prior to PPT. Any deviations from the software tested during FAT must be raised and justified - this can include the application of updates to address previous bugs or provide enhanced functionality.

3.2.4.2. Hardware

PPT utilises the availability of a substation RTU and DNO SCADA within a test environment owned by SSEN.

The test environment RTU must match the model of the substation RTU on-site, including any firmware and software versions. All software versions must be logged prior to commencing testing. The only material configuration difference is to be the addition of the new SCADA data points relative to the RaaS project.

The test DNO SCADA system is similarly used to match the system that exists on site. All software versions must match the software versions running on the DNO SCADA System and must be logged prior to testing, with the exception of any required additional configuration relative to the installation of the DNO RaaS Controller.

3.2.4.3. PPT (SSEN Test Environment) Simulations

The following simulations are used within this test environment:

- All messages sent between the BESS EMS and test Substation RTU.
- All required measurements from PQM including voltage, frequency and power.
- The status of the RaaS BESS transformer neutral earth contactor.

3.2.5. PPT (BESS Premises Environment)

To test the integration of the BESS EMS with the DNO RaaS Controller, if circumstances allow integration testing during the FAT of the BESS can be undertaken. This HiL environment is shown in Figure 3.

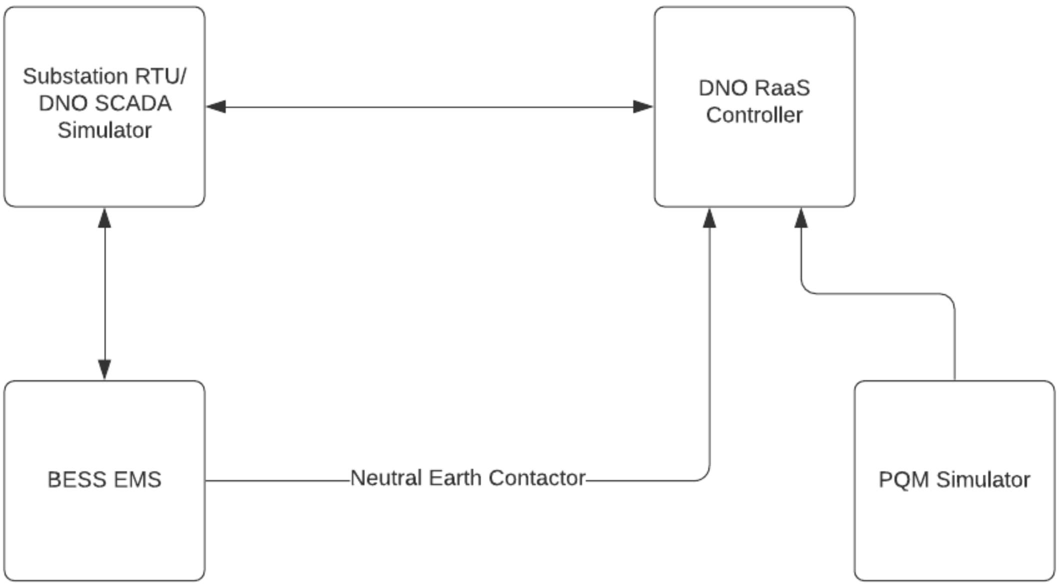

Figure 3 - PPT Environment: BESS EMS Premesis

3.2.5.1. Software

All DNO RaaS Controller software utilised in this testing must be logged prior to testing and must match the software used during the PPT within SSEN's test laboratory premises (where this is carried out prior to PPT during BESS FAT) or the DNO RaaS Controller FAT where PPT at the BESS EMS premises are carried out prior to PPT at SSEN's test laboratory . Any deviations must be raised and justified.

3.2.5.2. Hardware

The DNO RaaS Controller must be the same hardware tested during FAT and earlier PPT.

The connection from the BESS EMS transformer neutral earth contactor is implemented here if the test environment permits this. Otherwise, this should be simulated.

3.2.5.3. PPT (BESS Environment) Simulations

The following simulations are used within this test environment:

- All messages sent from the Substation RTU to BESS EMS.

- All messages sent from the Substation RTU to the DNO RaaS Controller.
- All required measurements from the PQM including voltage, frequency and power.
- The status of the RaaS BESS transformer neutral earth contactor (if required).

3.2.6. Site Acceptance Testing (SAT) Environment

Figure 4 shows a high level representation of the environment for Site Acceptance Testing (SAT) for the trial site, Drynoch Primary Substation.

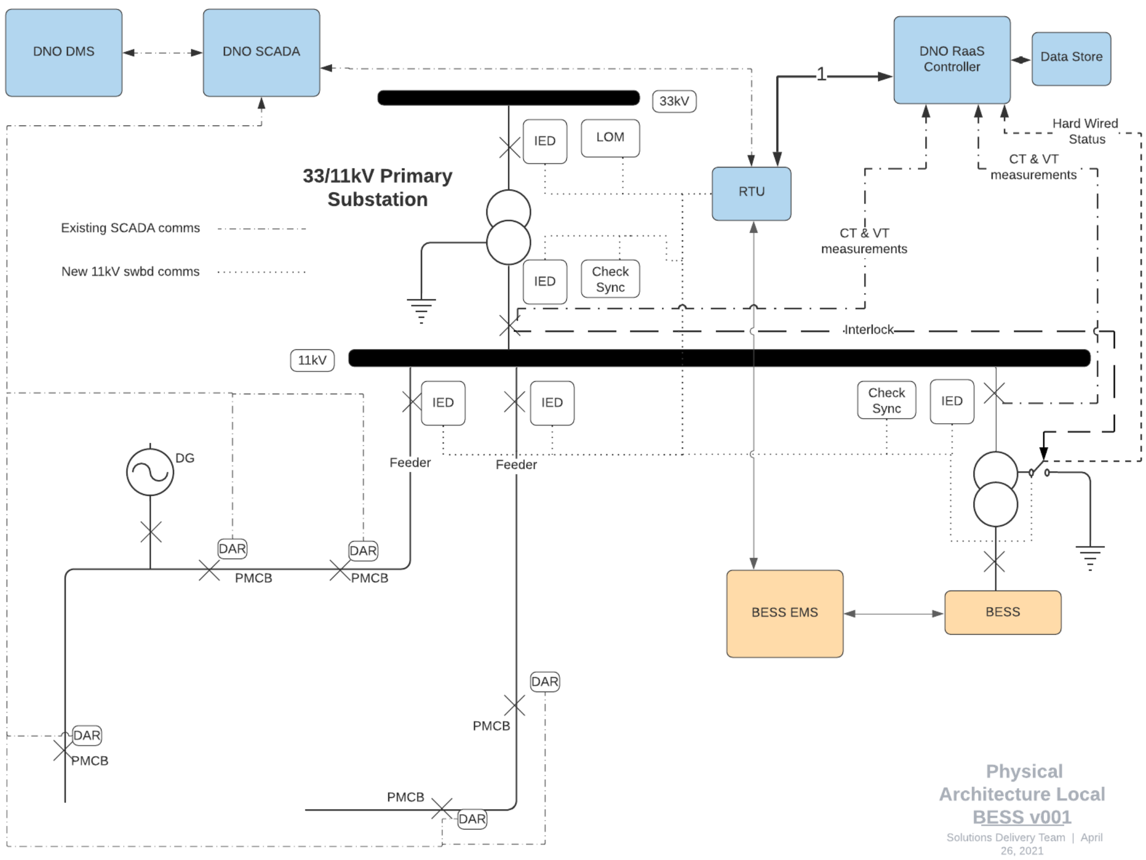

Figure 4 - SAT Environment (with Local BESS)

3.3. Test Procedures

3.3.1. Overview

This section provides a summary of the test types and test descriptions to be performed during each test stage (FAT, PPT and SAT) in the DNO RaaS Controller test program.

3.3.2. Test Types

The DNO RaaS Controller test programme includes the following three test types, with individual tests under each test type described in the tables indicated which are located in Section 3.3.4.

- **Table 3 - Environment (Hardware) Tests -** Environment tests are designed to validate that the hardware (physical or virtual) components within the system are fit for purpose.
- **Table 4 - Data Transfer Tests**. Data transfer tests validate communication and data exchange between all sub-system elements with application logic (designed algorithms) loaded. At FAT and PPT, missing external devices are simulated. During SAT, data transfer testing is essential and is based on the specific system and configuration data exchange for the device.
- **Table 5 - System Tests**. System tests are designed to test the behaviour of the system during both success and failure scenarios for the entire system. The system tests are aimed at demonstrating the effective implementation of the DNO RaaS Controller functional use cases set out in the Requirements and Use Case Specification [3]. The functional use cases identified within that report are listed in Table 6.

3.3.3. Black Start Site Acceptance Testing

Black start site acceptance testing presents the challenge of providing sufficient confidence in the ability of the RaaS system to carry out a BESS supported islanded network black start supply restoration sequence while also minimising supply disruption, or the risk of supply disruption, to customers during SAT testing[3].

The main technical challenge with supply restoration during a black start sequence is for the BESS to provide the transformer inrush current during switching into service of the feeder circuits (closing the primary substation 11kV feeder circuit breakers), and/or of sections of the feeder circuits (closing of specific pole mounted circuit breakers on each feeder). While this transformer inrush current only lasts for a very short duration (10s of milliseconds), if the current is sufficiently high the duration may compromise stable operation of the BESS and the overall RaaS system[4]. SSEN and E.ON have considered solutions to this issue in the RaaS FEED study report [2] and concluded that two solutions are viable to limit transformer inrush to tolerable levels, as described below.

The first option is to limit the capacity/number of transformers switched into service at any one time. This can be achieved by switching in limited sections of the 11kV feeders using the pole mounted circuit breakers (PMCB). Hence, restoring supplies to an 11kV feeder and associated customers requires a programmed sequence of circuit breaker closures[5]. Figure 5 extracted from the RaaS FEED study report illustrates the PMCB locations for the Drynoch trial site.

[3] SSEN and SGS have discussed the potential to carry out other specialist black start testing of the RaaS system prior to SAT e.g. at the Power Networks Demonstration Centre (PNDC) facility or using Real Time Dynamic Simulation. However, it has been agreed that this would be time consuming and expensive and would not provide clear benefits. Black starting ultimately requires going through SAT to provide SSEN sufficient confidence that it will work effectively as part of a RaaS system for BAU applications as well as the Drynoch trial.

[4] Statement based on information from the RaaS FEED study [2].

[5] Note, circuit breakers that are part of the supply restoration circuit breaker switching sequence require to be opened during the pr-energisation switching sequence for black starting the network island from the BESS.

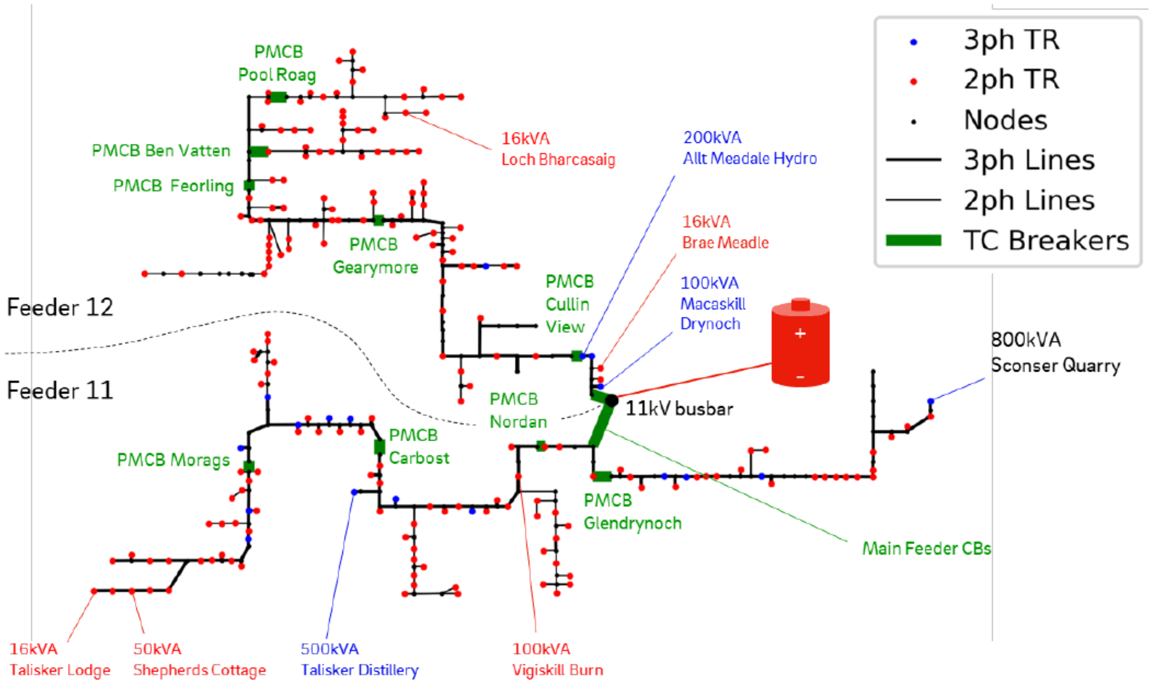

Figure 3 - Topological map of Drynoch 11kV network

Figure 5 - Topological map of Drynoch 11kV Network

The second option is to apply Point on Wave (PoW) switching for circuit breaker closure[6], which provides synchronised switching to allow a greater capacity/number of transformers to be energised at one time, and hence reduce the number of PMCB switching operations in the black start restoration switching sequence.

A reduction in the number of PMCB switching operations in the restoration sequence, and the time required between these to ensure that the BESS supported island remains stable during RaaS Islanded mode black start, is important as SSEN is targeting completion of supply restoration within 3 minutes of a system black out. This will avoid regulatory penalties for customer interruptions.

SSEN and E.ON continue to consider which specific technical solution to apply to the Drynoch trial site. However, whichever solution is adopted, the site acceptance testing is required to provide sufficient confidence to SSEN that a black start sequence can be successfully delivered by the overall RaaS scheme.

Table 5 presents the DNO RaaS Controller system tests developed with reference to the functional use cases listed in Table 6. Tests C15 to C22 relate to RaaS Islanded mode black start supply restoration and are described in Table 5 along with reference to the associated use cases. Implementing system tests C15 to C22 during SAT are discussed in section 3.3.5.

[6] Point-on-Wave switching eliminates the random nature of mechanical switching by using precision timing to control the exact moment of conduction that results in the minimum inrush current possible. By controlling the point of switching the impact of the residual flux in the transformer prior to switching can be minimised which reduces the transformer inrush current.

3.3.4. Test Descriptions

The descriptions of the tests included in the DNO RaaS Controller test programme under each of the three test types described in Section 3.3.2 are presented in the following tables. The tables also indicate the test stages that each test applies to.

Table 3 - Environment (Hardware) Tests

Test No.	Title	Aim of Test	Tested Component(s)	Test Stage Performed
A1	DNO RaaS Controller Power Up	Demonstrate that the DNO RaaS Controller Powers up and all processes and software start correctly.	DNO RaaS Controller	All

Table 4 - Data Transfer Tests

Test No.	Title	Aim of Test	Tested Component(s)	Test Stage Performed
B1	Substation RTU to DNO RaaS Controller	Demonstrate that all data sent from the Substation RTU to the DNO RaaS Controller is received.	DNO RaaS Controller, Substation RTU	All
B2	DNO RaaS Controller to Substation RTU	Demonstrate that all data sent from the DNO RaaS Controller to the Substation RTU is received.	DNO RaaS Controller, Substation RTU	All
B3	Substation RTU to DNO RaaS Controller Communications Failure: Grid plus RaaS BESS	Demonstrate that the DNO RaaS Controller raises a local alarm when communications with the Substation RTU are broken and that the DNO RaaS Controller attempts to re-establish communications until successful. An alert is raised on the BESS EMS and auto black start and auto transition to RaaS Islanded mode is disabled by the BESS EMS.	DNO RaaS Controller, Substation RTU, BESS EMS	PPT, SAT
B4	Substation RTU to DNO RaaS Controller Communications Failure: RaaS Islanded mode	Demonstrate that the DNO RaaS Controller raises a local alarm when communications with the Substation RTU are broken and that the DNO RaaS Controller attempts to re-establish communications until successful. An alert is raised on the BESS EMS and auto black start is disabled by the DNO RaaS Controller.	DNO RaaS Controller, Substation RTU, BESS EMS	PPT, SAT

Test No.	Title	Aim of Test	Tested Component(s)	Test Stage Performed
B5	Substation RTU to DNO RaaS Controller Communications Failure: Grid Only	Demonstrate that the DNO Control Room receives an alert that the Substation RTU has lost communications with the DNO RaaS Controller. The DNO RaaS Controller attempts to re-establish communications until successful.	DNO RaaS Controller, Substation RTU	PPT, SAT
B6	Substation RTU to DNO SCADA	Demonstrate that all data sent from the Substation RTU to DNO SCADA system is received.	Substation RTU, DNO SCADA	PPT, SAT
B7	DNO SCADA to Substation RTU	Demonstrate that all data sent from the DNO SCADA to the Substation RTU system is received.	Substation RTU, DNO SCADA	PPT, SAT
B8	DNO SCADA to Substation RTU Communications Failure	Demonstrate that the DNO SCADA raises an alarm when communications with the Substation RTU are broken and that the Substation RTU attempts to re-establish communications until successful.	Substation RTU, DNO SCADA	PPT, SAT
B9	Substation RTU to BESS EMS	Demonstrate that all data sent from the Substation RTU to the BESS EMS is received.	Substation RTU, BESS EMS	SAT
B10	BESS EMS to Substation RTU	Demonstrate that all data sent from the BESS EMS to the Substation RTU is received.	Substation RTU, BESS EMS	PPT, SAT
B11	Substation RTU to BESS EMS Communications Failure: Grid plus RaaS BESS	Demonstrate that the Substation RTU raises an alarm to the DNO SCADA and DNO RaaS Controller when the communications with the BESS EMS are broken and the Substation RTU attempts to re-establish communications until successful. Auto Black Start is disabled by the DNO RaaS Controller.	Substation RTU, BESS EMS	PPT, SAT
B12	Substation RTU to BESS EMS Communications Failure: RaaS Islanded mode	Demonstrate that the Substation RTU raises an alarm to the DNO SCADA and DNO RaaS Controller when the communications with the BESS EMS are broken and the Substation RTU attempts to re-establish communications until successful. Auto Black Start is disabled by the DNO RaaS Controller.	Substation RTU, BESS EMS	PPT, SAT
B13	Substation RTU to BESS EMS Communications Failure: Grid Only	Demonstrate that the Substation RTU raises an alarm to the DNO SCADA and DNO RaaS Controller when the communications with the BESS EMS are broken and the Substation RTU attempts to re-establish communications until successful.	Substation RTU, BESS EMS	PPT, SAT

Test No.	Title	Aim of Test	Tested Component(s)	Test Stage Performed
B14	Substation CTs/VTs to DNO RaaS Controller	Demonstrate that all measurements from the Substation CTs/VTs to the DNO RaaS Controller are received.	DNO RaaS Controller, Substation CTs/VTs	SAT
B15	Substation CTs/VTs to DNO RaaS Controller Failure	Demonstrate that the DNO RaaS Controller raises an alarm when a loss of current/voltage from any CT/VT is detected by the PQM module and that black start procedures are stopped. This can be achieved using the test terminals on modern CT/VTs.	DNO RaaS Controller	All
B15.1	Primary transformer 11kV circuit CT or VT communication failure (Grid plus RaaS BESS operation).	Demonstrate that if PQM module indicates a loss of current/voltage from the primary transformer CT or VT link, during Grid plus RaaS BESS operation that the DNO RaaS Controller will send signal to BESS EMS to move to a safe operating mode (defined by SSEN). Send signal to BESS EMS to block transition to RaaS Islanded mode.	DNO RaaS Controller, Primary transformer 11kV circuit CT and VT.	All
B15.2	Primary transformer 11kV circuit CT or VT communication failure (RaaS Islanded mode).	Demonstrate that if PQM module indicates a loss of current/voltage from the primary transformer CT or VT link, during BESS island operations that the DNO RaaS Controller will send a status update to DNO Control Room and alert to BESS Control Centre.	DNO RaaS Controller, Primary transformer 11kV circuit CT and VT.	All
B15.3	Primary transformer 11kV circuit CT or VT communication failure (Grid Only operation).	Demonstrate that if PQM module indicates a loss of current/voltage from the primary transformer CT or VT link, during Grid Only operation that the DNO RaaS Controller will disable closure of the RaaS BESS 11kV circuit breaker.	DNO RaaS Controller, Primary transformer 11kV circuit CT and VT.	All
B15.4	RaaS BESS transformer 11kV CT or VT (Grid plus RaaS BESS, RaaS Islanded mode and Grid Only operation).	Demonstrate that if PQM module indicates a loss of current/voltage from the RaaS BESS transformer 11kV CT or VT, the DNO RaaS Controller provides a status update to DNO Control Room and alert to BESS Control Centre.	DNO RaaS Controller, RaaS BESS transformer 11kV CT or VT.	All

Test No.	Title	Aim of Test	Tested Component(s)	Test Stage Performed
B15.5	11kV Busbar VT (Grid plus RaaS BESS, RaaS Islanded mode and Grid Only operation).	Demonstrate that if PQM module indicates a loss of current/voltage from the 11kV Busbar VT, the DNO RaaS Controller provides a status update to DNO Control Room and alert to BESS Control Centre.	DNO RaaS Controller, 11kV Busbar VT.	All
B15.6	RaaS BESS Transformer 11kV neutral earth contactor (Grid plus RaaS BESS operation) .	Demonstrate that if there is a fault on the signal from the RaaS BESS transformer 11kV neutral earth contactor, the DNO RaaS Controller sends a signal to BESS EMS to block transition to RaaS Islanded mode.	DNO RaaS Controller, RaaS BESS Transformer 11kV neutral earth contactor.	All
B15.7	RaaS BESS Transformer 11kV neutral earth contactor (RaaS Islanded mode).	Demonstrate that if there is a fault on the signal from the RaaS BESS Transformer 11kV neutral earth contactor that on synchronising the island with the Grid that the DNO RaaS Controller sends a signal to trip the RaaS BESS 11kV circuit breaker to avoid the risk of multiple 11kV system earths.	DNO RaaS Controller, RaaS BESS Transformer 11kV neutral earth contactor.	All
B15.8	RaaS BESS Transformer 11kV neutral earth contactor (Grid Only operation).	Demonstrate that if there is a fault on the signal from the RaaS BESS Transformer 11kV neutral earth contactor, the DNO RaaS Controller disables closure of the RaaS BESS 11kV circuit breaker to avoid the risk of multiple 11kV system earths.	DNO RaaS Controller, RaaS BESS Transformer 11kV neutral earth contactor.	All
B16	RaaS BESS Transformer Neutral Earth Contactor to DNO RaaS Controller	Demonstrate that the digital signal from the RaaS BESS Transformer Neutral Earth Contactor to the DNO RaaS Controller is received.	DNO RaaS Controller, RaaS BESS Transformer Neutral Earth Contactor	SAT
B17	RaaS BESS Transformer Neutral Earth Contactor to DNO RaaS Controller Failure	Demonstrate that the DNO RaaS Controller raises an alarm when there is a fault in the signal from the RaaS BESS Transformer Neutral Earth Contactor and that the BESS EMS is tripped.	DNO RaaS Controller	All

The system tests summarised in **Error! Reference source not found.**, are based on the DNO RaaS C ontroller functional use cases set out in the detailed requirements specification [3], with further detail on the functional control logic provided in the detailed design document [4]. A high-level description of each use case is provided in Table 6 as a point of reference within this report.

Table 5 - System Tests

Test No.	Title	Aim of Test	Associated Use Case	Tested Component(s)	Test Stage Performed
C1	DNO RaaS Controller User Interface Access Control	Demonstrate that the DNO RaaS Controller User Interface can be accessed only by authorised users and only users with suitable permissions have access to control actions and configuration of the DNO RaaS Controller.	N/A	DNO RaaS Controller User Interface	All
C2	Monitor BESS Readiness	Demonstrate that the DNO RaaS Controller alerts the DNO SCADA system when the BESS EMS is unavailable.	UC1	Complete System	All
C3	BESS Runtime Forecast	Demonstrate that the DNO RaaS Controller makes accurate predictions of the available island mode runtime of the BESS based on the monitoring of the BESS charge, primary transformer 11kV power flow and alerts the DNO SCADA system when this is too low for island mode operation.	UC1	DNO RaaS Controller	All
C4	Operational Mode Changes	Demonstrate that the DNO RaaS Controller can detect which mode the RaaS system is in based on observations of the network equipment (BESS plus Grid, RaaS Islanded, Grid Only, 11kV black out).	UC2, UC3, UC4, UC5, UC10	DNO RaaS Controller	All
C5	Grid plus RaaS BESS: DNO RaaS Controller 11kV Voltage Threshold Alerts	Demonstrate that the DNO RaaS Controller raises the correct alerts when upper and lower voltage thresholds are exceeded by configurable time limits.	UC4	DNO RaaS Controller, Substation RTU, DNO SCADA	All

Test No.	Title	Aim of Test	Associated Use Case	Tested Component(s)	Test Stage Performed
C6	Grid plus RaaS BESS: DNO RaaS Controller Primary Transformer Power Threshold Alerts	Demonstrate that the DNO RaaS Controller raises the correct alerts when upper and lower power thresholds are exceeded by configurable time limits.	UC4	DNO RaaS Controller, Substation RTU	All
C7	Grid plus RaaS BESS: DNO RaaS Controller Primary Transformer Power Threshold BESS Trip	Demonstrate that the DNO RaaS Controller trips the BESS 11kV CB when the BESS EMS when the upper and lower power thresholds are exceeded by configurable time limits.	UC4	DNO RaaS Controller, Substation RTU	All
C8	RaaS Islanded Operation: DNO RaaS Controller 11kV Voltage Threshold Alerts	Demonstrate that the DNO RaaS Controller raises the correct alerts when upper and lower voltage thresholds are exceeded by configurable time limits.	UC6	DNO RaaS Controller, Substation RTU	All
C9	RaaS Islanded Operation: DNO RaaS Controller 11kV Voltage Threshold BESS Trip	Demonstrate that the DNO RaaS Controller trips the BESS 11kV CB when the BESS EMS when the upper and lower voltage thresholds are exceeded by configurable time limits.	UC6	DNO RaaS Controller, Substation RTU	All
C10	RaaS Islanded Operation: DNO RaaS Controller Frequency Threshold Alerts	Demonstrate that the DNO RaaS Controller raises the correct alerts when upper and lower frequency thresholds are exceeded by configurable time limits.	UC6	DNO RaaS Controller, Substation RTU	All
C11	RaaS Islanded Operation: DNO RaaS Controller Frequency Threshold BESS Trip	Demonstrate that the DNO RaaS Controller trips the BESS 11kV CB when the BESS EMS when the upper and lower frequency thresholds are exceeded by configurable time limits.	UC6	DNO RaaS Controller, Substation RTU	All

Test No.	Title	Aim of Test	Associated Use Case	Tested Component(s)	Test Stage Performed
C12	Island-to-Grid: Request to Synchronise	Demonstrate that the DNO RaaS Controller can receive a request from the BESS EMS to synchronise to grid, and to issue permission based on the 11kV voltage and frequency indicating a return of Grid, and the auto synchronisation permissions from the DNO Control Room.	UC10	DNO RaaS Controller, DNO SCADA, BESS EMS	All
C13	Island-to-Grid: Synchronisation Procedure - Success	Demonstrate that when the BESS EMS has synchronised the RaaS Islanded network with the Grid supply and successfully closed the synchronising circuit breaker that the DNO RaaS Controller monitors that the 11kV voltage and frequency remain stable for the programmed period and confirms the BESS transformer 11kV neutral earth contactor is open before alerting the DNO Control Room that synchronisation is complete. Also that the DNO RaaS Controller then sends commands to any required primary substation protection devices to switch to grid mode setting groups. Also that the DNO RaaS Controller sends commands to the DNO DMS to remove any required PMCB DAR blocking.	UC10, U11	Complete System	All
C14	Island-to-Grid: Synchronisation Procedure - Failure	Demonstrate that the DNO RaaS Controller trips the BESS EMS under the failure conditions of the Automated Synchronisation Procedure (BESS transformer 11kV neutral earth contactor does not open when the primary transformer 11kV circuit breaker (synchronising circuit breaker) closes).	UC10, UC11	Complete System	All

Test No.	Title	Aim of Test	Associated Use Case	Tested Component(s)	Test Stage Performed
C15	Black Start: Commence	Demonstrate that where the DNO RaaS Controller has auto black start enabled, that it checks a black out condition exists and then issues a command to the DNO DMS to reconfigure the 11kV network ready to be energised by the RaaS BESS. The DNO DMS sends an acknowledgement to the DNO RaaS Controller when it has successfully completed its network switching sequence.	UC2, UC7	DNO RaaS Controller	All
C16	Black Start: Commence (disable auto black start)	Demonstrate that where the DNO RaaS Controller has auto black start enabled, that it checks a black out condition exists. If the primary transformer 11kV circuit breaker remains closed or the voltage or frequency at the primary substation 11kV busbars do not drop below the programmed thresholds, the DNO RaaS Controller disables auto black start and raises an alert to the DNO Control Room.	UC2, UC7	DNO RaaS Controller	All
C17	Black Start: Connect BESS - Success	Demonstrate that the DNO RaaS Controller issues the correct signals to the BESS EMS to energise the 11kV switchboard and checks that the neutral earth via the BESS 11kV transformer is established as well as monitoring the voltage and frequency for stability.	UC5, UC8	DNO RaaS Controller, Substation RTU, BESS	All
C18	Black Start: Connect BESS - Failure	Demonstrate that the DNO RaaS Controller trips the BESS when no neutral earth is detected and also on voltage and frequency instability.	UC5, UC8	DNO RaaS Controller, Substation RTU, BESS	All

Test No.	Title	Aim of Test	Associated Use Case	Tested Component(s)	Test Stage Performed
C19	Black Start: Restore Customer Supplies - Success	Demonstrate that the DNO RaaS Controller issues the supply restoration switching sequence initiation command to the DNO DMS, monitors the voltage and frequency stability between switching operations and receives an acknowledgement signal when the DNO DMS is finished the supply restoration switching sequence and continues to monitor voltage and frequency into fully restored RaaS Islanded operation.	UC9	DNO RaaS Controller, Substation RTU, BESS, DNO SCADA	All
C20	Black Start: Restore Customer Supplies - Failure 1	Demonstrate that the DNO RaaS Controller issues a command to stop the DNO DMS supply restoration switching sequence when the voltage and frequency are outside configured parameters. Demonstrate that when the DNO RaaS Controller monitors a return of stable voltage and frequency it sends a command to the DNO DMS to continue the supply restoration sequence.	UC9	DNO RaaS Controller, Substation RTU, BESS, DNO SCADA	All
C21	Black Start: Restore Customer Supplies - Failure 2	Demonstrate that the DNO RaaS Controller trips the BESS while the DNO DMS carries out the supply restoration Black Start switching sequence when the voltage and frequency are outside configured parameters. Demonstrate that the DNO RaaS Controller returns to the start of the black start process and commences again at UC-2 (check for a black out condition) and incrementing the Black Start commencement count by 1.	UC2, UC7, UC8, UC9	DNO RaaS Controller, Substation RTU, BESS, DNO SCADA	All

Test No.	Title	Aim of Test	Associated Use Case	Tested Component(s)	Test Stage Performed
C22	Black Start: Restore Customer Supplies - Failure 3	Repeat test C22 with the black start commencement updating by 1 each time until the count reaches a programmed number of commencements. Demonstrate that when the DNO RaaS Controller trips the BESS while the DNO DMS carries out the supply restoration Black Start switching sequence when the voltage and frequency are outside configured parameters, that this time the DNO RaaS Controller stops the black start sequence and issues a status update to the DNO Control Room that the black start has stopped.	UC2, UC7, UC8, UC9	DNO RaaS Controller, Substation RTU, BESS, DNO SCADA	All

Table 6 - DNO RaaS Controller Use Cases

Use Case	Description
UC1	RaaS BESS Readiness Status
UC2	Grid plus RaaS BESS 11kV Blackout Condition Monitoring
UC3	Grid plus RaaS BESS Transition to RaaS Island Operation – Monitoring
UC4	Grid plus RaaS BESS Primary Substation Transformer Thermal and 11kV Voltage Out of Limits Monitoring
UC5	Island Condition 11kV Earth Check, Protection Setting Switching and DAR Blocking
UC6	Island Condition Primary 11kV Substation Frequency and Voltage Stability Monitoring
UC7	Blackout, Reconfiguration of Island Network Ready for Black Start
UC8	Blackout, Energise Reconfigured Primary Substation 11kV Switchboard
UC9	Island Blackout Network and Customer Supply Restoration CB Switching
UC10	BESS Island Network Permission to Synchronise with the Grid
UC11	Grid plus RaaS BESS Condition Restore Protection Settings and DAR Switching

3.3.5. Implementing Black Start Acceptance Testing (SAT)

The DNO RaaS Controller requirements and uses cases covering BESS supported islanded black start are documented in the Requirements and Use Case Specification [3]. The aims of system tests C15 to C22 are provided in Table 5 above, and the implementation of the related SATs are discussed in the following sections. This includes consideration of how tests C15 to C22 can be broken down, and the order in which they are carried out to minimise customer interruptions. The aim is to test the functionality described in the referenced use cases including the failure responses detailed in the use cases.

There are three main components to the black start sequence where the DNO RaaS Controller functionality requires to be demonstrated during SAT, including the response to specific failure conditions. These are summarised as follows, with further detail on implementation given below:

SAT Component 1. The DNO RaaS Controller Identifies that a black out condition exists and commands the DNO DMS to reconfigure the 11kV network ready to be energised by the RaaS BESS, receiving a DNO DMS acknowledgement signal once network switching has been successfully completed. The DNO RaaS Controller also checks that the primary substation transformer 11kV circuit breaker has been opened by the RaaS loss of mains (LOM) protection scheme (external to the DNO RaaS Controller). This functionality is covered in system tests C15 and C16.

SAT Component 2. Having isolated the primary substation 11kV switchboard from the 11kV and 33kV network in 1 above, the DNO RaaS Controller energises the primary substation 11kV switchboard from the RaaS BESS. This includes a failure scenario where the 11kV system earth has failed. This functionality is covered in system tests C17 and C18.

SAT Component 3. With a BESS supplied primary substation 11kV switchboard established (including the 11kV earth), the DNO RaaS Controller commands the DNO DMS to commence its programmed supply restoration circuit breaker switching sequence. The DNO

RaaS Controller then monitors the voltage and frequency stability between DNO DMS switching operations and receives an acknowledgement signal when the DNO DMS is finished the supply restoration switching sequence. The DNO RaaS Controller then continues to monitor voltage and frequency into fully restored RaaS Islanded operation. This is covered by system test C19. System tests C20 to C22 cover specific DNO RaaS Controller functional responses to voltage and frequency stability issues encountered during the DNO DMS supply restoration switching sequence.

3.3.5.1. SAT Component 1 and 2

To carry out SAT Components 1 and 2 described above, the 11kV feeders could be isolated from the Drynoch primary substation and supplied from an alternative source during the testing e.g. a suitable 11kV supply from another primary substation where available (e.g. it may be possible to supply Drynoch via the 11 kV network from Dunvegan and Lower Ollach) or from suitable temporary diesel generation capability.

3.3.5.2. SAT Component 3

SAT component 3 is more complex and more disruptive to customers as it cannot be carried out without supply disruption to customers. It is also the case that the impact on RaaS BESS stability when switching in feeder circuit sections during islanded mode, and the associated transformer inrush currents, will not be fully known until the SAT is carried out.

One way to minimise the potential risks to customer supply disruption would be to reverse the black start supply restoration sequence or test specific switching elements out of sequence, before testing in sequence. Using this approach, instead of commencing testing in RaaS Islanded mode with the feeder circuit breakers and any required PMCBs open (therefore with no supply to customers) and then switching in the first feeder circuit section, testing commences with a transition from Grid plus RaaS BESS operation to RaaS Islanded mode (note that this requires SAT system tests C1 to C12 to have been completed first). In this situation all customers would remain on supply. To then test and gain confidence in the black start restoration sequence, a circuit section at a feeder end could be switched out using the associated PMCB, and then switched back in to restore supplies with monitoring used to obtain data on the island network voltage and frequency impacts of supply restoration. If this is successful, two PMCBs in the feeder switching sequence could then be opened and then closed according to the black start supply restoration sequence. The monitored voltage and frequency data during these activities could be used to make a decision regarding carrying out a full 11kV feeder restoration switching sequence starting at the primary substation 11kV feeder circuit breaker. The data can also be used to determine a safe time between supply restoration switching events. Where Point on Wave (PoW) switching is adopted by SSEN, this may reduce the number of switching events programmed into the DNO DMS switching sequence to restore customer supplies (possibly allowing an entire 11kV feeder circuits to be restored using one switching operation at the 11kV primary substation).

A further advantage to this approach is that if instability is experienced causing the RaaS BESS to trip, supplies can be quickly restored from the grid by the DNO Control Room closing the primary transformer 11kV circuit breaker.

Once SSEN is satisfied with the performance of the supply restoration switching sequence tests described above, and if deemed necessary, the feeder breakers and required PMCBs could all be opened while in RaaS Islanded mode and the DNO DMS allowed to run through the complete black start supply restoration sequence, monitored by the DNO RaaS Controller. This would complete SAT C19.

Voltage and frequency stability thresholds could then also be altered to allow restoration sequence failure tests C20 , C21 and C22 to be carried out.

Development of the final arrangements for SAT Component 3 testing by the RaaS project team is still ongoing.

4. DNO RAAS CONTROLLER INSTALLATION AND COMMISSIONING PROGRAMME

The DNO RaaS Controller installation and commissioning programme is closely linked with the DNO RaaS Controller test programme set out in section 3 and the installation and commissioning programme for the other elements of the RaaS scheme trial. This includes the installation and commissioning of the new primary substation 11kV switchboard; the RaaS BESS, BESS EMS and other RaaS Service Provider facilities (e.g. the BESS Control Centre); and SSEN modifications to their DNO DMS to facilitate the commands to and data, alerts and status updates from the DNO RaaS Controller. SSEN and their partner companies will coordinate the installation and commissioning of all RaaS system components to enable the DNO RaaS Controller SAT to be completed.

The DNO RaaS Controller installation and commissioning programme will also depend on agreement with the appointed DNO RaaS Controller vendor and their delivery schedule.

Drawing on SGS's extensive experience in building, installing, integrating, testing and commissioning ANM and DERMS control solutions, we have set out the main tasks and estimated timescales for each activity, see Table 7. Figure 6 illustrates the estimated timeframes for the tasks presented in Table 7. However, this is not intended to represent a full project programme time scale as some tasks will be dependent on other RaaS system partner inputs which could extend the programme illustrated in Figure 6. Such tasks include Pre-Production Testing (PPT), for which both the test facilities at SSEN and BESS/BESS EMS vendor resources will need to be available, and Site Acceptance Testing (SAT), where the full RaaS system (DNO and third party elements) must be available (including primary substation equipment, BESS and BESS EMS, and modifications to the DNO DMS implemented by SSEN).

Table 7 following, presents an informed view of potential timeframes for RaaS testing based on SGS involvement with similar prior projects.

Table 7 - DNO RaaS Controller Estimated Delivery Timescales and Supplier Person Days Effort Estimate

Programme Item	Timescale	Vendor Estimated Person Days	Responsibility	Comments
Contract commences, vendor mobilisation.	2 weeks	5	SSEN, DNO RaaS Controller Supplier	Vendor attendance at kick off meetings to bring vendor up to speed. Vendor mobilises team and sets out any internal processes and plans required.
Vendor Procurement	4-10 weeks	5	DNO RaaS Controller Supplier	Vendor procures required hardware and third party software licenses required for the DNO RaaS Controller

Programme Item	Timescale	Vendor Estimated Person Days	Responsibility	Comments
Build DNO RaaS Controller including software design & Control Panel Design and acceptance testing strategy (ATS).	16 weeks	115	DNO RaaS Controller Supplier	Vendor builds and programmes the controller ready for FAT, includes collaboration with RaaS team during this process.
Acceptance Test Specification	2 weeks	10	DNO RaaS Controller Supplier	Detailed Acceptance Test Specification to meet the test criteria specified in this document.
FAT Test Development	1 week	5	DNO RaaS Controller Supplier	The test environment to be used during FAT is built.
FAT	2 weeks	10	DNO RaaS Controller Supplier, SSEN	Including controller amendments, retesting and FAT report.
PPT Test Integration (SSEN Premises)	2 weeks	10	DNO RaaS Controller Supplier, SSEN	Substation RTU and SCADA system on SSEN's test environment are integrated with DNO RaaS Controller and BESS EMS simulator.
PPT (SSEN Premises)	2 weeks	10	DNO RaaS Controller Supplier, SSEN	Including controller amendments, retesting and PPT report.
PPT Test harness integration (BESS EMS Premises)	1 week	5	DNO RaaS Controller Supplier, SSEN, BESS EMS Supplier	DNO RaaS Controller integrated with BESS EMS test environment.
PPT (BESS EMS Premises)	2 weeks	10	DNO RaaS Controller Supplier, SSEN, BESS EMS Supplier	Including controller amendments, retesting and PPT report.
Site Integration Works	4 weeks	20	DNO RaaS Controller Supplier, SSEN, BESS EMS Supplier	DNO RaaS Controller and BESS EMS are integrated along with Substation RTU and DNO SCADA configuration updates. All communications links established and tested.

Programme Item	Timescale	Vendor Estimated Person Days	Responsibility	Comments
SAT	4 weeks	20	DNO RaaS Controller Supplier, SSEN, BESS EMS Supplier	Including controller amendments, retesting and SAT report.
Manual/User Guide written and staff training on DNO RaaS Controller and handover.	2 weeks	10	DNO RaaS Controller Supplier, SSEN	Provide training to SSEN staff who will be looking after the DNO RaaS Controller during the trial. This will potentially include Control Room engineers, IT/OT staff and maintenance engineers.

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION
Contract commences, vendor mobilisation.	1	2	1	2
Vendor Procurement	1	10	1	10
Build DNO RaaS Controller including Control Panel build	3	16	3	16
Acceptance Test Specification	19	2	19	2
FAT Test harness development	19	2	19	2
FAT	21	1	21	1
PPT Test harness integration (SSEN Premises)*	22	2	22	2
PPT (SSEN Premises)	24	2	24	2
PPT Test harness integration (BESS EMS Premises)**	26	1	26	1
PPT (BESS EMS Premises)	27	2	27	2
Site integration works***	29	4	29	4
SAT	33	4	33	4
Staff training on DNO RaaS Controller and handover.	37	2	37	2

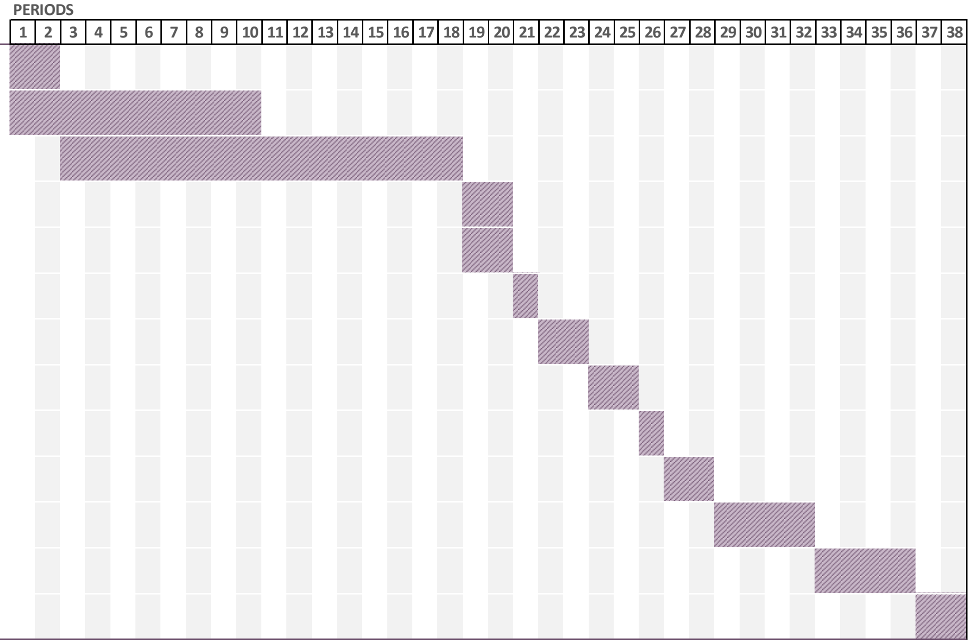

Figure 6 - Gantt Chart for Proposed Project Test Schedule

Notes:

* Assumed that SSEN Substation RTU and DNO SCADA system test facility has been updated and is ready for DNO RaaS Controller PPT.

** Assumed that BESS EMS/BESS vendor development is complete and ready for DNO RaaS Controller PPT.

*** Assumed that suitable arrangements are in place on site ready for DNO RaaS Controller integration works. Also all RaaS scheme installation and integration works will be ready for DNO RaaS Controller SAT at the end of this programmed period.

5. DNO RAAS CONTROLLER COST ASSUMPTIONS FOR PROCUREMENT AND INSTALLATION

This section provides cost estimates for the procurement of the DNO RaaS Controller based on the programme activities listed in Table 7. The costs are broken down into DNO RaaS Controller vendor hardware and labour cost estimates and are described in sections 5.1 and 5.2 respectively. All costs exclude VAT and delivery.

5.1. DNO RaaS Controller Hardware Cost Estimates

5.1.1. Control Module

Suitable general purpose RTU compliant with IEEE 1613 and meeting all hardware and operating requirements described in the RaaS DSO Controller Requirements Specification [3].

Approximately £6000.

5.1.2. PQM Module

Suitable PQM Module capable of providing power quality data to the DNO RaaS Controller.

Approximately £7000.

5.1.3. I/O Modules

Digital Input Module capable of transmitting the RaaS BESS transformer neutral earth contactor status along with diagnostics to DNO RaaS Controller.

Approximately £600.

5.1.4. Communications Modules

Industrial Layer 2 Switch capable of meeting operational requirements.

Approximately £200.

5.1.5. Control Panel

Typical small Control Panel design, build and supply.

Approximately £6000.

5.1.6. HMI

Industrial HMI.

Approximately £1000.

5.2. DNO RaaS Controller Labour Cost Estimates

Labour costs for vendors will vary. SGS has assumed a blended rate across the staff disciplines and staff grades that a vendor may apply to this project. In order to provide an upper and lower cost range estimate for procurement of the DNO RaaS Controller SGS has also assumed an upper and lower blended day rate of £1000/day and £700/day, respectively. These rates have been applied to the estimated vendor person days of effort for each activity listed in Table 7 to determine the total upper and lower labour cost estimates.

5.3. Cost Summary

The estimated vendor costs for the supply, installation and commissioning of the DNO RaaS Controller including the FAT, PPT and SAT programme of tests described in section 3 are summarised in Table 8. Costs for testing during PPT at the BESS facility FAT testing and at the SSEN test facility are included. The cost estimates do not include vendor software license or third party license costs. Software licence costs are vender specific where these exist and cannot be estimated by SGS. Any costs for load banks, secondary injection test equipment, diesel generators etc. associated with testing are not included. Costs for any additional testing at a specialist test facility such as PNDC are also not included.

Table 8 - Cost Summary

Activity/Procurement	**Cost (Lower Estimate, £)**	**Cost (Upper Range, £)**
Labour Costs		
Contract commences, vendor mobilisation.	3500	5000
Vendor Procurement	3500	5000
DNO RaaS Controller Design and Programming	80500	115000
Acceptance Test Specification	7000	10000
Testing: FAT	10500	15000
Testing: PPT	24500	35000
Site Integration/Commissioning	14000	20000
Testing: SAT	14000	20000
Manual/User Guide written and staff training on DNO RaaS Controller and handover	7000	10000
Project Management	26600	38000
Hardware Costs		
Control Module	6000	
PQM Module	7000	
I/O Module	600	
Communications Modules	200	
HMI	1000	
Control Panel Design & Build	6000	
Total Labour and Hardware Cost	**211,900**	**282,400**

6. APPENDIX 1 - SSEN SWP3 LIST OF SCOPE OF WORK ITEMS

SWP 3 - Detailed DNO Scheme Design for the Selected Trial Site (1 primary substation site)

Summary:

1. Review of the outputs of SWP1, SWP2 and other relevant project material which describes the RaaS concept and is available to promote effective collaboration between all those involved in development of the scheme.

2. Capture all project and operational requirements and ensure that these are factored into the scheme design and functionality to be provided by the DNO side aspects of the RaaS system - the scheme design should support integration with a range of different primary substation configurations (e.g. numbers of transformers, RTUs, etc.) and be compatible with a range of applicable communications standards and protocols, with the capability to accommodate site specific factors in a clear way when implementing the system at any individual substation.

3. Create a detailed system architecture for the DNO side aspects of the RaaS system including its integration with existing SSEN assets and its interface with the external elements of the RaaS scheme - the architecture must be clearly represented to promote communication and understanding, and the use of frameworks such as SGAM[7] (Smart Grid Architecture Model) is welcomed.

4. Define the DNO side operational functions required for the implementation of RaaS, and where these functions best sit across the decentralised and centralised elements of primary substation operation.

5. Identify the DNO staff roles & responsibilities associated with the use of RaaS to support SSEN network operation in the event of a fault.

6. Evaluate and develop step-by-step process(es) for DNO side information exchanges and actions required to utilise RaaS to support SSEN network operation in the event of a fault and interface with the external elements of the RaaS scheme for each of the operational scenarios set out in Table 1 - this should identify all automated and/or manual information exchange steps between DNO devices/systems/parties, and across interfaces/boundaries with third party systems (e.g. status information, command signals, acknowledgement signals, time to readiness/readiness/completion information, voltage data, frequency data, synchronisation information, etc.)

7. Represent the information exchange requirements between all devices, systems and/or individuals clearly through appropriate diagrams, flow charts, etc.

8. Identify and detail the potential risks of RaaS operation and associated mitigation measures.

9. Define requirements and recommendations for development of the DNO RaaS Platform (the purpose of this platform is to provide automated control of the DNO side elements of using RaaS to support SSEN network operation in the event of a fault and to provide the system interface with the external RaaS Controller and other third-party assets).

10. Create a flow chart for the logic to be applied via the DNO RaaS Platform which represents the required algorithm segments, data points and detailed control logic.

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[7] The SGAM framework was created by the CEN-CENELEC-ETSI Smart Grid Coordination Group in response to Mandate M/490 issued by the European Commission in 2011 - CEN (European Committee for Standardization), CENELEC (European Committee for Electrotechnical Standardisation), ETSI (European Telecommunications Standards Institute).

11. Produce proposed modifications to the existing SCADA system or other relevant business communications systems.

12. Produce a proposed specification for the information and alarms to be shown in the DMS or other relevant business systems.

13. Detail the communications media, communications protocols and information standards required to implement RaaS, including interfacing the DNO RaaS Platform with the external RaaS Controller and other third-party assets, and applying the required the protection and control schemes.

14. Provide recommendations and identify options regarding the reliability of comms required to use RaaS to support SSEN network operation in the event of a fault.

15. Identify factors relevant to cyber risk and information security associated with the implementation of RaaS.

16. Develop a testing programme for the DNO side aspects of the RaaS system which demonstrates its integration with existing SSEN assets and its interfaces with the external elements of the RaaS scheme, in addition to its capability to operate as required - this should be aligned to the testing activities planned by other project partners, and should apply a staged approach to allow issues to be identified in a timely manner prior to further development or more involved testing activities, e.g. comprising Factory Acceptance Testing (FAT), bench testing, hardware-in-the-loop testing, and full commissioning testing.

17. Develop an installation & commissioning programme for the DNO side aspects of the RaaS system - this should be aligned with the installation & commissioning activities planned by other project partners.

18. Provide refined cost assumptions for procurement & installation of all DNO side aspects of the RaaS system (including its integration with existing SSEN assets and its interface with the external elements of the RaaS scheme).

19. Liaise closely with the RaaS project partners to understand and align the development of the detailed DNO scheme design for RaaS with the detailed design for third party elements (i.e. RaaS Controller, BESS, DER).

20. Arrange site visits as appropriate, via the SSEN RaaS project team.

21. Comply with SSEN safety requirements and expectations, including attending SSEN Safety Briefings as required, prior to any site activities commencing.

22. Maintain regular contact with the SSEN RaaS project team to report on progress and raise any potential issues at the earliest opportunity.

23. Provide a report describing the work undertaken (including data used and any assumptions made) and detailing all findings and recommendations.

24. Support project dissemination activities as appropriate.