RaaS
Resilience as a Service

Project Deliverable 2
Detailed Design

Scottish & Southern Electricity Networks

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Document Ownership

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Version Control

Version	Date	Authors	Status
1.0	29/10/2021	Sarah Rigby	Final version for submission following SSEN internal review and sign-off

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Project Overview

The Resilience as a Service - RaaS - innovation project seeks to improve the operational resilience of electricity distribution networks in remote areas.

The aim is to develop and trial a new market-based solution which can swiftly, automatically, restore supply to customers in the event of a fault, using services provided by a local Battery Energy Storage System, and incorporating local Distributed Energy Resources. Figure 1 provides a high level illustration of the RaaS scheme.

The RaaS concept represents a flexible solution for areas where traditional reinforcement or use of DNO owned standby generation to provide network resilience would be prohibitively costly. Through temporary operation of the network in islanded[1] mode, RaaS will maintain supply to customers during the time required for a DNO to respond to a fault. At other times, a RaaS Service Provider would be able to use the battery to provide other services to the electricity system, supporting the economics of the solution.

The key benefits of this approach in providing cost effective, local network resilience will include an improved service to customers, together with a lower carbon solution than the conventional option of transporting a temporary diesel generator to site, supporting the UK's transition to Net Zero.

The project is a partnership between Scottish and Southern Electricity Networks (SSEN), E.ON and Costain, with funding of £10.9m through Ofgem's Network Innovation Competition (NIC).

In addition to demonstrating the technical concept, the work will develop the commercial framework for RaaS - evaluating the financial case from a DNO perspective and assessing the investment case for RaaS Service Providers with options for revenue stacking in other flexibility services markets.

The first phase of the project focuses on site selection, system design for the chosen demonstration site, and refinement of the business case for RaaS. This stage will validate whether the concept is technically feasible and financially viable, to inform a Stage Gate decision towards the end of 2021 on whether to proceed with the deployment and operation of a RaaS system at the chosen site for a trial period of up to two years.

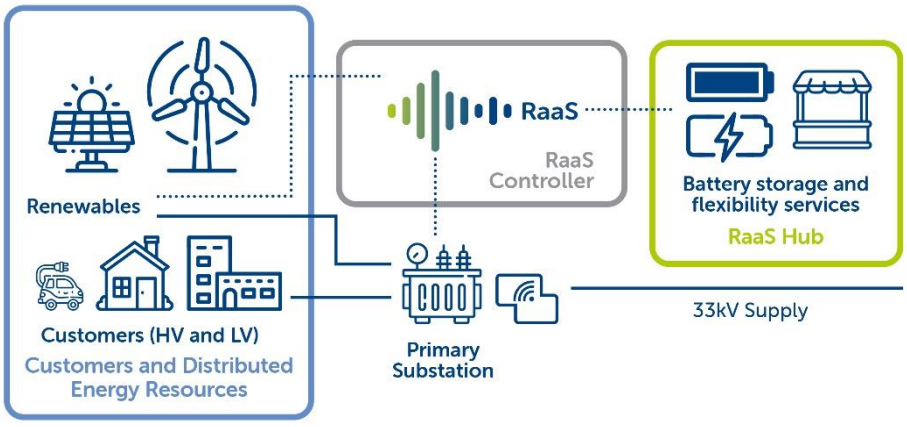


Figure 1 - Schematic of the RaaS solution supporting a 33kV to 11kV primary substation

[1] in islanded mode, an area of the network is disconnected from the main electricity grid and operates independently

Introduction to PD2

This PD2 overview document sets out the work undertaken within the RaaS - Resilience as a Service - project to meet the requirements of Project Deliverable 2 - Detailed Design, defined in the Project Direction as:

> RaaS Project Deliverable 2
>
> > PD2.1 Detailed design of controls, electrical integration, available DER and the BESS complete
> >
> > PD2.2 Publish Trial Programme on SSEN RaaS webpage

The paper introduces the work undertaken to develop a detailed technical design for applying a RaaS solution. The accompanying design documents address both the Battery Energy Storage System (BESS) and its controls, and the DNO side system architecture which will interface with that third party system and give visibility and command capability to the central DNO Control Room. The detailed design builds on the Front End Engineering Design (FEED)[2] created to present initial proposals for the design of the RaaS scheme, and reflects the valuable feedback received through the external FEED peer review process, reported in Project Deliverable 1.

This Project Deliverable, together with associated project material, will be published on the project website - www.project-raas.co.uk - and made available to all interested parties.

To provide the context for PD2, Appendix 1 presents the Project Deliverables defined in the RaaS Project Direction.

[2] RaaS 'Front End Engineering Design (FEED)' V2 (E2a.2), E.ON, February 2021

RaaS Detailed Design

Context

The technical application of a RaaS solution would comprise both DNO and 'third party' assets and control systems.

To support a 33/11 kV primary substation, the DNO owned substation would have an interface with the third party owned RaaS controller, and that controller would respond to a loss of supply signal from the substation to automatically restore supply to the 11 kV network via a battery as the 'anchor generator', together with subsequent export from local renewable or distributed energy resources. The DNO side system architecture would also provide command capability and visibility of the RaaS scheme to the central DNO Control Room.

A RaaS event would see the 11 kV network operate in islanded mode, and depending on the type of fault experienced, the battery energy storage system (BESS) would provide fault ride through with a seamless transition, or provide a swift black start response. Accordingly, RaaS has four key operational processes:

- fault ride through - transitioning to islanded operation (supply via RaaS BESS) without interruption after a network fault
- black start - restoring the network in islanded operation (supply via RaaS BESS) after a network fault which has caused a blackout on the 11 kV busbar
- adapting islanded operation (supply via RaaS BESS) to incorporate temporary mobile generation despatched to support a longer term fault
- transferring from RaaS back to conventional network operation

The RaaS controller would also incorporate functionality which allows the BESS to provide other services to the electricity system, supporting wider use cases and revenue stacking from other markets.

The design work undertaken during Phase 1 of the project has looked in detail at the RaaS operational scenarios associated with grid connected and islanded mode, and each of the transitions between the different operational states, to develop electrical and control system architectures, including appropriate protection and earthing schemes, to provide the required RaaS functionality and operate the scheme safely.

Within the project, SSEN and E.ON are developing the 'DNO side' and 'third party side' systems and interfaces in a way that will give clear boundaries between the DNO and future RaaS Service Providers, and be replicable both for application to other substations on SSEN's network, and for adoption by other DNOs across Great Britain.

Detailed Design for a RaaS Battery Energy Storage System and Associated Control Scheme

The initial FEED report provided an extensive description of the requirements of a BESS scheme capable of delivering the functionalities necessary to implement RaaS, however this was based on generic BESS models.

The subsequent Detailed Design Report (DDR) prepared by E.ON refines this assessment through the incorporation of studies provided by battery suppliers, utilising BESS system models with vendor specific control firmware and electrical parameters. Information from potential BESS suppliers was obtained through an initial Request for Information (RfI) stage to shortlist potential suppliers, and Request for Proposals (RfP) from those shortlisted.

The DDR considers topics associated with each mode of operation of RaaS, and the transitions between the different RaaS operational states, as represented in Figure 2.

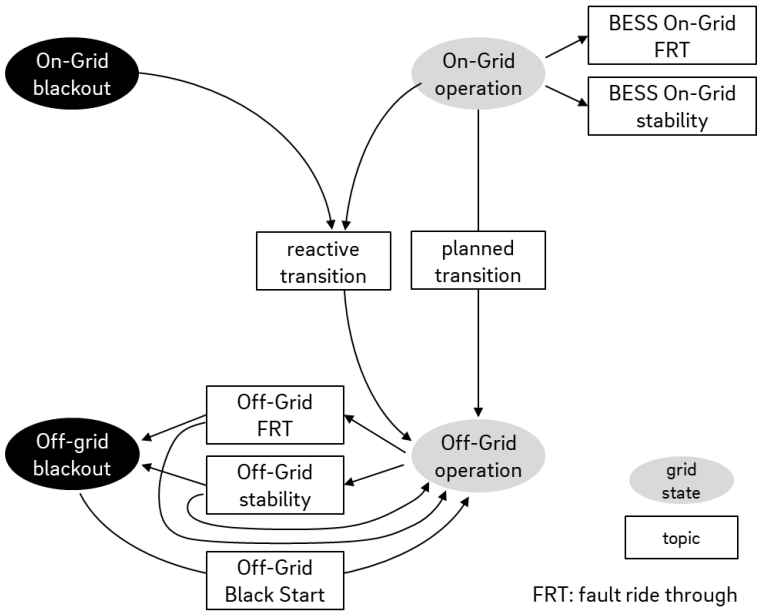


Figure 2 - Topics addressed in the BESS Detailed Design report

Subject to a positive Stage Gate decision, the DDR will be used to prepare a Request for Quotes (RfQ) which will be issued as part of the tendering and procurement process for delivery of the trial scheme at the selected trial site of Drynoch on the west coast of Skye in Scotland. This trial phase would commence in 2022.

The E.ON Detailed Design Report is provided as Appendix 2.

Detailed Design for the DNO Elements of a RaaS Scheme

To support development of the DNO elements of a RaaS scheme, SSEN undertook a tender process in October 2020 to appoint suitable consultants for each of the following SSEN Work Packages (SWPs):

- SWP1 - Modelling and Feasibility Study on the RaaS Concept Applied at Primary Substation Level
- SWP2 - Modelling of the Inrush Currents Experienced During a RaaS Black Start Operational Scenario
- SWP3 - Detailed DNO Scheme Design for the Selected Trial Site
- SWP4 - Protection and Control Settings Study for the Selected Trial Site
- SWP5 - DNO Business Case Update

In addition, a Point on Wave[3] (PoW) switching study was sought to investigate any potential benefits of applying a synchronised switching device to control inrush currents during RaaS network energisation.

The network modelling, PoW switching, and protection scheme studies provided information relevant both to the detailed design of the DNO side scheme, and to the design and assessment of the third party system developed by E.ON. The deliverables from the associated SWPs 1, 2 & 4 are set out below.

SWP1 - Modelling and Feasibility Study on the RaaS Concept Applied at Primary Substation Level

- Suitable network/power flow models to represent the areas of network to be assessed
- Modelling to assess the impact on network operation of each of the RaaS operational scenarios, include the following steady state and dynamic studies and analysis:
  - power flow analysis
  - voltage studies
  - transients & system stability analysis
  - assessment of fault contributions of the different system components under each scenario
- Insight from the modelling work which:
  - identifies the general and site specific requirements, challenges and risks associated with enabling islanded operation from individual primary substations (inc. considerations relevant to network energisation from a grid forming generator with additional Distributed Energy Resources (DER))
  - assesses the implications of transitioning to islanded operation (supply via RaaS), on the existing protection settings for DNO assets (33 kV, 11 kV, LV), and identifies requirements for protection settings across third party elements of a RaaS scheme (inc. RaaS Controller, BESS, DER)
  - identifies all requirements to ensure that the BESS system can provide adequate voltage control via reactive power compensation in islanded operation
  - defines the DNO side processes, and identifies any associated conditions/requirements, for initiating and completing all actions necessary to operate RaaS safely and maintain compliance with all relevant codes and standards under each of the RaaS operational scenarios
  - makes recommendations regarding suitable earthing solutions for the integration of existing SSEN assets with the BESS system, and identifies specific products that will meet requirements

[3] Point on Wave switching reduces inrush currents experienced by transformers and other electrical assets when a mechanical circuit breaker operates to energise a section of network - a synchronised switching device offers an electronic solution which can be installed to control the circuit breakers and manage switching transients (momentary changes in voltage or current) which may otherwise damage electrical assets

- establishes whether any of the DER protection settings (associated with G59/G99 grid connection standards) would need to be adjusted for islanded operation and supply via RaaS
- represents the DNO elements and interfaces necessary for the integration of existing SSEN assets with the full RaaS scheme

The SWP1 reports describing the work which has contributed to the detailed design of a RaaS scheme are provided as Appendices 3 & 4.

SWP2 - Modelling of the Inrush Currents Experienced During a RaaS Black Start Operational Scenario

- Modelling to determine inrush currents when re-energising the network during a RaaS Black Start
- Identification and appraisal of options to minimise inrush currents on the downstream network based on both feasibility and effectiveness - including:
  - tele-controlled reconfiguration of the 11 kV network
  - application of controlled Point on Wave switching
  - inverter over-rating required
- Evaluation of the feasibility and implications of a RaaS Black Start process which applies a soft start with customers connected - including consideration of the expected customer experience, and assessments of the impact that this would have on different types of devices/appliances

The SWP2 reports describing the work which has supported assessment of the detailed design for a RaaS scheme are listed as Appendices 5 & 6.

The PoW switching studies report forms Appendix 7.

SWP4 - Protection and Control Settings Study for the Selected Trial Site

- Detailed analysis of the potential impacts of the proposed BESS installation (as set out in the FEED) on network operation, protection settings, stability, DER operation, and safety
- Identification of changes/additions to the existing protection schemes required for the implementation of RaaS
- A bespoke, detailed design of the protection and control schemes for implementing RaaS at the trial site (inc. protection systems/devices, configurations & settings)
- Proposed protection scheme drawings including modifications following SSEN Protection team review

The SWP4 report describing the protection coordination studies which have informed development of the detailed design for RaaS is provided as Appendix 8. The protection and control schemes for the proposed trial site would be completed once information about the specific battery system and DNO equipment to be installed for the trial is confirmed following the tendering and procurement processes to be undertaken during Phase 2 of the project, subject to a positive Stage Gate decision.

The detailed design for the DNO side electrical and control system architecture was then created through SWP3, and comprises the information set out below.

SWP3 - Detailed DNO Scheme Design for the Selected Trial Site

- Documentation of all project and operational requirements to 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 has been developed to 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
- 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
- Description of 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
- Identification of the DNO staff roles & responsibilities associated with the use of RaaS to support SSEN network operation in the event of a fault
- Development and evaluation of 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 - including identification of 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.)
- Representations of the information exchange requirements between all devices, systems and/or individuals clearly through appropriate diagrams, flow charts, etc.
- An assessment of the potential risks of RaaS operation and associated mitigation measures
- Comprehensive information on the 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)
- 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
- Recommendations for proposed modifications to the existing SCADA system or other relevant business communications systems
- A proposed specification for the information and alarms to be shown in the DNO's Distribution Management System (DMS) or other relevant business systems
- Detail on 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 protection and control schemes
- Recommendations regarding options for the reliability of comms required to use RaaS to support SSEN network operation in the event of a fault
- Information on factors relevant to cyber risk and information security associated with the implementation of RaaS
- 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, be aligned to the testing activities planned by other project partners - this applies a staged approach to allow issues to be identified in a timely manner prior to further development or more involved testing activities, i.e. comprising

Factory Acceptance Testing (FAT), bench testing, hardware-in-the-loop (HITL) testing, and full commissioning testing

- An installation & commissioning programme for the DNO side aspects of the RaaS system, aligned with the installation & commissioning activities planned by other project partners
- 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)

The SWP3 reports describing the development of the DNO side aspects of a RaaS scheme comprise Appendices 9 to 12.

The detailed design reports delivered through Phase 1 of the RaaS project, together with deliverables focusing on the commercial aspects of RaaS, are available via the project website - www.project-raas.co.uk.

Conclusions

The breadth of work undertaken to create each aspect of the detailed design for a RaaS scheme supports the understanding that it is technically feasible to implement a solution that can swiftly, automatically, restore supply to customers in the event of a fault, using services provided by a local Battery Energy Storage System, and incorporating local Distributed Energy Resources.

Detailed consideration of the different RaaS operational scenarios, and the transitions between these, indicates that it is possible to operate RaaS safely and maintain compliance with all relevant codes and standards under each of the associated network arrangements. However, some uncertainties remain with regard to the capability of the BESS to transition seamlessly from grid connected to islanded operation after a fault particularly close to the substation busbar, and the capability of the BESS to withstand the potential inrush current during black start. These factors cannot be fully understood at this stage due to the absence of prior experience and supporting data associated with this novel application of a BESS, accordingly such potential risks and mitigation measures would be evaluated in detail during the testing stages of the trial phase of the project.

The results of the PoW switching studies indicated that using a synchronised switching device on each feeder is possibly a suitable solution to mitigate inrush currents, however, it is difficult to analyse and establish the potential level of reduction due to uncertain flux patterns associated with the single phase and three-phase transformers. PoW switching therefore represents an option for incorporation into the scheme in the event that testing indicates that the BESS would require supplementary capability to manage inrush currents.

The detailed design documents created through Phase 1 of the project, and described within this PD2 overview document, provide a comprehensive suite of material which can be used for tendering and procurement of the BESS and DNO side aspects of RaaS during Phase 2 of the project, subject to a positive Stage Gate decision.

The project's progression to Phase 2 would then give the opportunity to install and demonstrate this technical solution to provide fault response and local resilience, including detailed aspects around network protection, fault levels, and voltage stability. In addition to providing significant learning for the future application of RaaS, this trial could provide some key learning for other dynamic solutions for network operation and resilience[4].

[4] as one example here, the RaaS project team are engaged with National Grid ESO's Distributed ReStart team to share learning on the challenges and synergies of providing resilience at different voltage levels - Distributed ReStart explores the use of DER to restore power in the highly unlikely event of a total or partial blackout of the GB electricity transmission system - www.nationalgrideso.com/future-energy/projects/distributed-restart

Proposed Trial Programme

Publication of Trial Programme Information via the Project Website

For the proposed trial demonstration of RaaS during Phase 2 of the project, subject to a positive stage gate decision, project partner E.ON will fulfil the role of the third party RaaS Service Provider. The text below has been prepared to give a high level overview of the proposals for trial operation of the RaaS scheme at Drynoch, and has been published on the project website - www.project-raas.co.uk.

Subject to a positive stage gate decision, the intention is to install a battery for the demonstration and trial operation of a RaaS scheme at SSEN's Drynoch primary substation on the Isle of Skye. The scheme would be capable of providing discharge power of 6MVA for up to 3 seconds and 3MW during continuous operation, and depending on the cell technology applied, it is expected that the battery would have a capacity of at least 3MWh.

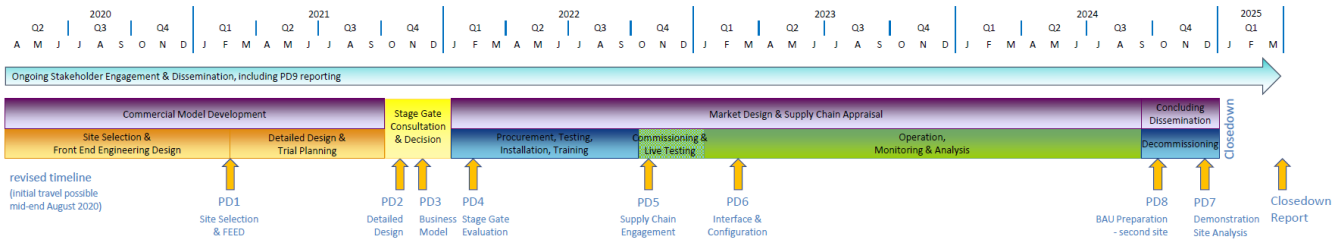
In addition to providing storage capacity for both the RaaS service and participation in other flexibility markets, this battery system would ensure appropriate integration with the existing network protection schemes for the safe operation of RaaS, including transitions between grid connected and islanded operation, and provide the power required to successfully black start the Drynoch 11kV network.

Initially, sufficient energy will be reserved in the battery to supply the Drynoch site for 3 hours, across 90% of the year - this would cover a high proportion of power outages based on historic data. The remaining 'headroom' capacity will be used for revenue optimisation from other markets and services, such as wholesale trading, the Balancing Mechanism, Frequency Response/Dynamic Containment, and the Capacity Market. During the trial period, the operational procedures will be evaluated and refined to further optimise the balance of reserved and headroom capacity, supporting the cost effective delivery of local resilience.

In addition to demonstrating the technical and commercial concepts, the project will investigate a range of other factors identified as influential for the future application and roll out of RaaS, including:

- the approach to DNO service level requirements specification
- the role of forecasting, including the potential benefits from enhanced forecasting of:
  - demand - to inform DNO requirements specification and reserved capacity at different points in time
  - interruptions - to inform DNO decisions re 'standing down' a RaaS service to release battery capacity for other markets
  - income from other markets - to inform RaaS Service Provider decisions re battery sizing and optimal headroom capacity (and then determine RaaS fees)
- RaaS fees structures - preferences around the proportion of fixed, availability & utilisation payments, considerations regarding contract vs incentives - rewards & penalties

The image below indicates the timeline for the two stages of the project.



Contact Details

Interested parties are very welcome to contact the RaaS project team with any enquiries via the contact details below:

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Appendices

Appendix 1 - RaaS Project Deliverables

Appendix 2 - Detailed Design Report for the RaaS BESS & EMS, E.ON, October 2021

SWP1

Appendix 3 - RaaS Sites Review and Technical Modelling Requirements (SWP1 D1), WSP, February 2021

Appendix 4 - Network Model Development and Validation for RaaS Feasibility Studies - Drynoch and Kinloch Distribution Networks (SWP1 D3), WSP, October 2021

SWP2

Appendix 5 - Modelling and Simulation Studies of Inrush Current Phenomena Associated with the Application of RaaS Drynoch Distribution Network (SWP2 D2), WSP, July 2021

Appendix 6 - Evaluation of Islanded Network Black Start Capability - RaaS Scheme (SWP2 D3), WSP, October 2021

Appendix 7 - RaaS Site Energisation / PoW Switching Study - Drynoch, Enspec, May 2021

SWP4

Appendix 8 - RaaS Protection Coordination Studies (SWP4 D2), WSP, October 2021

SWP3

Appendix 9 - DNO RaaS System Requirements & Use Case Specification (SWP3 D1), SGS, May 2021

Appendix 10 - DNO RaaS System Detailed Design Specification (SWP3 D2), SGS, June 2021

Appendix 11 - DNO RaaS System Trial Testing, Installation and Commissioning Plan and Budgetary Cost Estimate (SWP3 D3), SGS, July 2021

Appendix 12 - SWP3 Summary Report (SWP3 D4), SGS, August 2021

Appendix 1 - RaaS Project Deliverables

To provide the context for PD2, Table 1 presents the Project Deliverables defined in the RaaS Project Direction.

Table 1 - RaaS Project Deliverables

Deliverable	Description	Evidence
1	Front End Engineering Design (FEED)	Report detailing the selected site for demonstration and proposed use case(s) for the RaaS demonstration. External peer review of FEED.
2	Detailed Design	Detailed design of controls, electrical integration, available DER and the BESS complete. Publish Trial Programme on SSEN RaaS webpage.
3	Business Model for potential RaaS suppliers	Construct investment business case for RaaS supplier. Produce draft Heads of Terms for RaaS method.
4	Stakeholder Feedback Event (Stage Gate)	Stakeholder feedback event to disseminate and gather feedback on outputs.
5	Supply Chain Engagement	Publish Commercial Strategy on SSEN RaaS webpage. Present Enterprise design for Resilience as a Service on SSEN website.
6	Network Adaptation and Acceptance Testing	Produce interface and configuration specifications and commissioning reports.
7	Trial 1 - Demonstration at first site complete	Publish Demonstration analysis results on SSEN RaaS webpage covering both technical and commercial aspects. Stakeholder dissemination event showcasing learnings.
8	BAU Preparation	Technical design to support second demonstration site. Consultation with potential RaaS market for second demonstration site.
9	Comply with knowledge transfer requirements of the Governance Document	Annual Project Progress Reports which comply with the requirements of the Governance Document. Completed Close Down Report which complies with the requirements of the Governance Document. Evidence of attendance and participation in the Annual Conference as described in the Governance Document.