Distributed ReStart

Energy restoration for tomorrow

Operating a Distribution Restoration Zone
September 2021

In partnership with:

tnei

SP ENERGY NETWORKS

nationalgridESO

Contents

Abstract

The Distributed ReStart project is a partnership between National Grid Electricity System Operator (NGESO), SP Energy Networks (SPEN) and TNEI (a specialist energy consultancy) that has been awarded £10.3 million of Network Innovation Competition (NIC) funding.

The project is exploring how distributed energy resources (DERs) can be used to restore power in the highly unlikely event of a total or partial shutdown of the National Electricity Transmission System (NETS). Past and current approaches rely on large power stations, but as the UK moves to cleaner and more decentralised energy, new options must be developed. The enormous growth in DERs presents an opportunity to develop a radically different approach to system restoration. Greater diversity in Black Start provision will improve resilience and increase competition, leading to reductions in both cost and carbon emissions. However, there are significant technical, organisational and commercial challenges to address.

The project is tackling these challenges (Jan 2019 – June 2022) and aims to develop and demonstrate new approaches, with initial procurement of Black Start service from DERs from mid-2022 if deemed feasible and cost-effective. Case studies on the SP Distribution (SPD) and SP Manweb (SPM) networks will be used to explore options then design and test solutions through a combination of detailed off-line analysis, stakeholder engagement and industry consultation, desktop exercises, and real-life trials of the re-energisation process.

Project Description

The project is made up of five workstreams. The Project Direction and Knowledge Dissemination workstreams cover the effective management of the project and ensure stakeholders are considered and communicated with throughout all project deliverables. The other three workstreams cover the wide range of issues to enable Black Start services from DERs:

- The Organisational, Systems and Telecoms (OST) workstream is considering the DER-based restoration process in terms of the different roles, responsibilities and relationships needed across the industry to implement at scale. It is developing requirements for information systems and telecommunications, recognising the need for resilience and the challenges of coordinating Black Start across a large number of parties. Proposed processes and working methods have been created and refined and have now been consulted upon with various stakeholders.
- The Power Engineering and Trials (PET) workstream is concerned with assessing the capability of GB distribution networks and installed DERs to deliver an effective restoration service. It will identify the technical requirements that should apply on an enduring basis. This will be done through detailed analysis of the case studies and progression through multiple stages of review. It will be tested through demonstration of the Black Start from DERs concept in 'live trials' on SPEN networks.
- The Procurement and Compliance (P&C) workstream is addressing the best way to deliver the concept for customers. It explores the options and trade-offs between competitive procurement solutions and mandated elements. It uses a strategic process to develop fit-for-purpose commercial solutions that are open and transparent, stakeholder endorsed and designed end-to-end with the commercial objectives of the project and workstream in mind. It will feed into business-as-usual activities to make changes as necessary in codes and regulations.

Keep up to date and find all other project reports here: **nationalgrideso.com/innovation/projects/distributed-restart**

Executive Summary

This report is the primary refine stage deliverable from the Organisational, Systems and Telecommunications (OST) workstream. It should be read alongside the Design Stage I report, published in October 2020, and the Design Stage II report, published in December 2020.

Throughout this document, we have refined our initial designs from design stages 1 and 2 to produce this final proposal for a Distributed ReStart organisational process design. This final design proposed has been subject to rigorous stakeholder review, in order to demonstrate the feasibility of Distributed ReStart. This report identifies the changes that are necessary to deliver this process design and proposes options for business readiness to enable impacted organisations to implement Distributed ReStart procedures.

The Design Stage I report focused on:

- methodology for development of the operational telecommunications' functional specifications
- initial cost estimates and methodology for development of cost case studies
- initial end-to-end cyber-resilience methodology and mitigation assessment
- systems considered essential to Distributed ReStart
- an introduction to the distributed energy resources (DER) control interface.

The Design Stage II report focused on:

- regulatory guidance for cyber security
- functional specifications for operational telecommunications
- costs associated with the operational telecommunications case studies
- end-to-end cyber-resilience analysis
- gap analysis of the current and required DER control interface.

This Refine Stage report focuses on:

- the Electricity System Restoration Standard (ESRS)
- stakeholder engagement feedback, critique and recommendations for refinements to the restoration process
- the restoration process using Distributed Resources and the practicalities of how this is managed and delivered by each organisation involved
- organisational impacts and considerations around training and change management.

The Electricity System Restoration Standard (ESRS)

In addition to the overall decarbonisation of the electricity network and the associated drive towards net zero by 2050, the introduction of a new ESRS by the Department for Business, Energy and Industrial Strategy (BEIS) creates a further need for distribution level restoration options to be included. Subject to the outcomes of final consultation, there will be a new requirement to restore demand to 60 per cent within 24 hours and 100 per cent within 5 days by December 2026. This represents a step change from the existing approach as this target is set regionally, meaning all areas must be able to achieve this consistent rate of restoration.

Across this report, it is demonstrated that there are a range of possible restoration options for using DERs to deliver against this standard. All make use of distribution restoration zones (DRZs); these are a collection of energy resources, demand and network that are co-located in order to create a stable power island that may achieve multiple different goals. While all these options deliver against the standard, the reasons that different restoration strategies would be used will be based on system studies and alignment with regional and national demands. The chosen option(s) would be pre-agreed within the restoration plans and the routes arranged in preference order.

Stakeholder engagement feedback, critique and recommendations for refinements to the restoration process

In the Design Stage I report, a proposal on organisational structure and process design was presented. This framework has been rigorously tested through stakeholder input across the remainder of the project, and this has been achieved through multiple different formats, with multiple different audiences, in the interests of reaching as widely as possible and incorporating views of others into the final proposal. We have used multiple different media types to reach audiences, using podcasts, desktop exercises, academic review, internal and external workshops and presentations to raise awareness and seek input.

Critical to this development has been the inputs received from desktop exercises; these were hosted on a custom-developed simulation platform allowing for direct input to advance the restoration event and allowing for cross-entity input on a single platform. These exercises were conducted across three different simulation events, enabling attendance from control engineers from all the GB distribution network owners (DNOs), transmission network owners (TOs) and energy and transmission authorised National Grid Electricity System Operator (NGESO) engineers. Furthermore, we reached 21 different representative distributed energy resources businesses and 8 different academic or other industry expert organisations. All direct feedback and questions have been captured and responded to in this report, but significant findings are explored in more detail to show how they have influenced change in the proposed process. Key outputs include:

Communications: There is a requirement for improved clarity, more specific data exchange requirements and streamlining of communications that were not required operationally.

Sequence of actions: There is a requirement to consider the risk of a single demand source, and there is a requirement to issue a 0MW setpoint to the DER ahead of energising its auxiliaries.

Command and control: In Scotland, it was considered acceptable for the DNO to maintain responsibility for frequency and voltage while a transmission network energy resource is energised. However, this can only apply where it is part of the pre-agreed plan. In the rest of GB, DNOs would only be the frequency lead for distribution-connected resources.

Timing: It was discussed that top-up service providers need to be assumed to take at least 20 minutes to provide their services to accommodate for most likely technology types.

Data: Desktop exercises identified two new data signals that we need to capture as part of the distribution restoration zone (DRZ) control system, ‘reactive power available’ and ‘state of charge’.

Robustness of the procedure: The simulation platform would be required to include failure modes if it were to be used for training.

The outputs from this desktop exercise were presented in a viva style approach to the NGESO Engineering Advisory Council (EAC) in order to seek further scrutiny of this process from a non-operational audience with wide-ranging engineering knowledge. This provides further credibility to the design proposal.

Finally, post-delivery of desktop exercises, the project put the outputs of the procedural design, including identified improvements, up for challenge and review by NGESO’s EAC function ensuring that an academic review has been provided to complement operational experience with robust critical analysis. A briefing report, presentation and extensive questioning has resulted in further improvements being implemented into the process design, and a record of all the questions is included in Appendix 1. The changes that we have made in response to EAC feedback are documented in Chapter 9.

The restoration process using Distributed Resources and the practicalities of how this is managed and delivered by each organisation involved

A key element of this report is the end-to-end process map presented in Chapter 5. This is the output of the co-creation activities, alongside incorporation of the key wider technical findings and control system developments. The restoration procedure considers the roles all service providers and network operators must take in order to grow a DRZ power island and incorporate it into national strategy. It presents the key metrics including:

- maximum time to delivery
- estimated numbers of people required
- key systems used to deliver the action
- the requirement for training.

Furthermore, the interfaces between organisations are classified by the type of communications that they require against our functional telecommunications specification, representing a 'letting go' of existing NGESO/TO responsibilities, and this was widely discussed and commented on during the desktop exercises.

The final process design clearly leads to a degree of Organisational, Systems and Telecommunications change. These are considered in the report across Chapter 6, providing an analysis for all organisations across each process stage. This analysis considers the new interfaces that will be introduced, the new systems that will be required, the new training and people that may be needed and any regional differences introduced. The major change identified as an issue for further consideration across roll-out is the frequency management capabilities of distribution network operator (DNO) control engineers in the event of automation failure. Training alone may not be enough to mitigate against this risk unless future distribution system operators operate in islanded mode for periods of time.

In addition to reviewing the change requirements, an assessment was conducted on the restoration timescales that may be achieved by a distribution restoration zone (DRZ) making use of the proposed systems and automation. It was found that a DRZ may take up to 14 hours to deliver a transmission level service, but this is dependent on the technologies involved. After this initial power island is grown, up to eight hours of network preparation, information gathering and distributed energy resources (DERs) readiness steps could be mitigated bringing economies of scale to the procedure.

Organisational impacts and considerations around training and change management

As the final report in the series of organisational and procedural design publications, it is important to illustrate how these proposals can be effectively integrated into business procedures, consolidating learnings from across the project into clear but non-restricting recommendations for the organisations involved. Each business involved will have their own change management strategy; for this reason, all key Organisational, Systems and Telecommunications changes introduced are summarised in Chapter 7 for consideration.

Conclusion and next steps

This report presents the findings and final refinement for a Distributed ReStart Restoration Process, along with guidance for all parties involved in this future restoration process around the following considerations:

1. Interfaces
2. Systems
3. Telecommunications requirements
4. Training requirements
5. Staff requirements
6. External factors

Overall, the introduction of Distributed ReStart will impose changes on the current way that Black Start processes and procedures are implemented and managed. However, the use of the central model, automation via DNO adoption of the distribution restoration zone controller (DRZ-C) functional specification (specific to their unique communications infrastructure and configuration) and new training procedures using simulation case studies minimises these impacts as far as possible. The resourcing impacts are mitigated almost entirely by using the DRZ-C, to the point where most DNOs would only see a minimal full time equivalent (FTE) requirement in most implementations.

From a stakeholder engagement perspective, it's clear that the energy industry have a deep interest in this new restoration process and their part in making it a success for the GB electricity networks. The use of the desktop exercises, and the way that they have been structured and delivered, has enabled a culture of 'continuous improvement' between project and stakeholders, and this is evident in the feedback we have received progressing through this final report stage.

We hope you enjoy reading this report and commend its findings and recommendations to stakeholders, customers and the government bodies we continue to work with.

1 Introduction

1.1 This Report

This report follows on from other reports written by the Organisational, Systems and Telecommunications workstream – Organisational, Systems and Telecommunications Design Stage II report **(nationalgrideso.com/document/182841/download)**, Design Stage I report **(nationalgrideso.com/document/178271/download)** and Operational, System and Telecommunications Viability report **(nationalgrideso.com/document/156216/download)** delivered in December 2020, October 2020 and November 2019 respectively.

The viability report identified the main challenges to delivering Distributed ReStart and considered a range of telecommunication options available to deliver these. We presented all widely known operational telecommunication options and developed a set of organisational models to illustrate possible stakeholder roles in delivering Distributed ReStart.

In the Design Stage I report, we developed the four organisational models initially proposed and then adopted a preferred way forward for the organisational design – the central model, which aligns with the distribution network operators (DNOs) automated control model. Initial functional requirements for operational telecommunications and technology frameworks were developed, and we carried out end-to-end cyber security assessments for the four organisational models.

Design Stage II was used to conclude the functional specifications for the central model, including the manual restoration process. Through a case study assessment, we derived the cost for providing the functional specification for the Central Model, including the manual restoration process to give average costs for service roll-out. The project carried out a review of the recently published distributed energy resources (DER) Cyber Connection Guidance, analysed what that would mean for Distributed ReStart and made recommendations on additional areas that need to be addressed. Further cyber analysis centred on the central model with recommendations made. In addition, a review of the DER communication and control interface was carried out with the view of incorporating learnings into the distribution restoration zone controller (DRZ-C) design and build.

Our focus for this report is to report on the outcome of the desktop exercises we carried out to test Distributed ReStart processes in terms of the roles for each Black-Start participant, and the timing of the process through simulation of events. These exercises also allowed the project to increase stakeholder participation in Distributed ReStart to gain valuable feedback for process refinement, work through a range of scenarios and gain information for future development of high-level training plans.

1.2 Report Structure

In the course of this report, we completed three desktop exercises by building a simulation tool, engaged a wider range of stakeholders – Transmission Owners (TOs), DNOs and DERs – and walked through the restoration process using a test defined restoration route. We also discussed and got feedback from stakeholders including industry experts and academia through these exercises. This was fed back into refining the process. The report is detailed under the following headings:

1.2.1 Key Concepts for Distribution Level Restoration

The Electricity System Operator, TOs and DNOs play active roles in restoring the electricity system during total or partial shutdown. DERs will join the list of active participants roles in system restoration with the roll-out of Distributed ReStart. These different organisations play varied and crucial roles in system restoration.

The project developed key concepts used throughout the various reports. Distribution restoration zone (DRZ), distribution restoration zone controller (DRZ-C) and various acronyms were used.

1.2.2 Electricity System Restoration Standard

The Black Start Strategy and Procurement Methodology sets out guidelines on how National Grid ESO cater for electricity restoration in event of partial or total power outage. The new Electricity System Restoration Standard (ESRS) when implemented will set new targets on timelines and regional capability for demand restoration in GB. Implementation of the ESRS will lead to National Grid Electricity System Operator (NGESO) licence modifications for compliance with the standard.

Distributed ReStart has the potential to play a major role in enabling meeting the regional restoration targets required by the Electricity System Restoration Standard.

1.2.3 Stakeholder Engagement

We understand the importance of this and have engaged stakeholders widely, as it has been a critical element of refining our organisational and process designs to work for end users.

We have consulted and sought feedback across all GB energy-network companies. This helped develop an understanding of the challenges in applying this methodology GB-wide to accommodate the varying differences across the companies. We have also engaged industry experts and academia through various international fora.

The various engagement fora include podcasts, desktop exercises and presentation at NGESO Engineering Advisory Council. These stakeholder reviews and challenge has informed and refined our thinking, resulting in the proposed organisational design.

1.2.4 Refine Stage Outputs

The simulation tool used for the desktop exercises was a custom-developed, web-based solution that could be accessed from anywhere without requiring the participants to install any special software. It was built around the Chapelcross network, and it is meant to emulate the control room environments for the different stakeholders, providing a 'real-time' view of the electrical network under their control, and enabling them to perform switching actions on the distribution and transmission network to restore power supply.

The project established key learning themes across the desktop exercises, and this fed indirectly into the process design. These themes are grouped and cut across communications, sequence of actions, command and control, timings, data, robustness of the operational procedure and options for future training roll-out.

It has been important to align the distribution restoration zone controller (DRZ-C) design and build of DRZ-C, which is a key and ongoing development for the project, and organisational requirements into a single procedure which makes use of the functionality that has been developed and considers human interaction and visibility requirements. This design makes use of functional blocks which can be called upon across the restoration event to automate elements of the procedure, while retaining control engineer approval for transition between phases.

1.2.5 Restoration Procedure

The proposed end-to-end restoration procedure details the automation systems used, the likely numbers of people involved, the responsible organisations and the communications method where applicable.

1.2.6 Process Analysis

The process design covered Black Start declaration, information gathering, instruction of DRZ, pre-energisation, anchor distributed energy resources (DER) stabilisation, DRZ growth, transmission network energisation, power island growth and end of DRZ. These process design segments were assessed against impacts to interfaces, systems, telecommunication requirements, training requirements, staff requirements and where it impacts on regional differences. These assessments were checked for the different Distributed ReStart participants – NGESO, transmission network owners (TOs), distribution network operators (DNOs) and (distributed energy resources) DERs.

We have compiled credible durations for restorations through applying the process design and reviewing the various options for delivery. We then estimated the maximum time to deliver the process from the outcome of consultations across the design and refine stage, cutting across consultations, desktop exercises and consideration of DRZ-C automatic actions.

1.2.7 Learnings for Roll-out

This chapter consolidates the learnings from across the project into clear but non-restricting recommendations for the organisations involved. These proposals can be effectively integrated into business procedures.

It will provide analysis of the likely impacts of integration with existing Black Start processes and procedures, any impacts or synergies observed with the wider transition towards active DER participation in markets and consideration of the ongoing development of distribution system operator (DSO) capabilities.

This is intended as a documentation of the requirements for implementation of the process for Distributed ReStart across the different participating organisations. These requirements cut across organisational impact assessment; processes, procedures and training; systems, tools and data requirements, and external factors.

1.3 Wider Restoration Roadmap

The diagram below shows how Distributed ReStart will fit into the wider restoration roadmap.

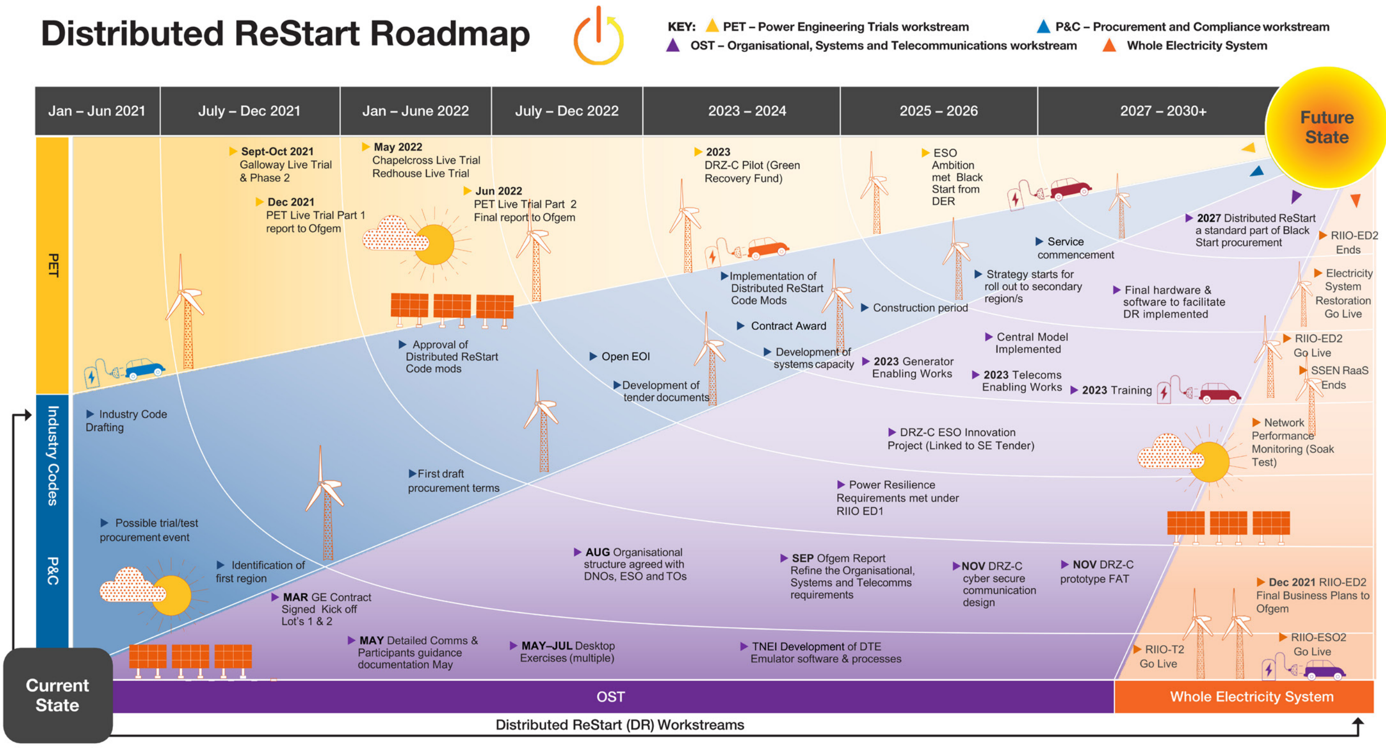


Figure 1: Restoration roadmap

Figure 2: Map showing location of transmission licence area boundaries

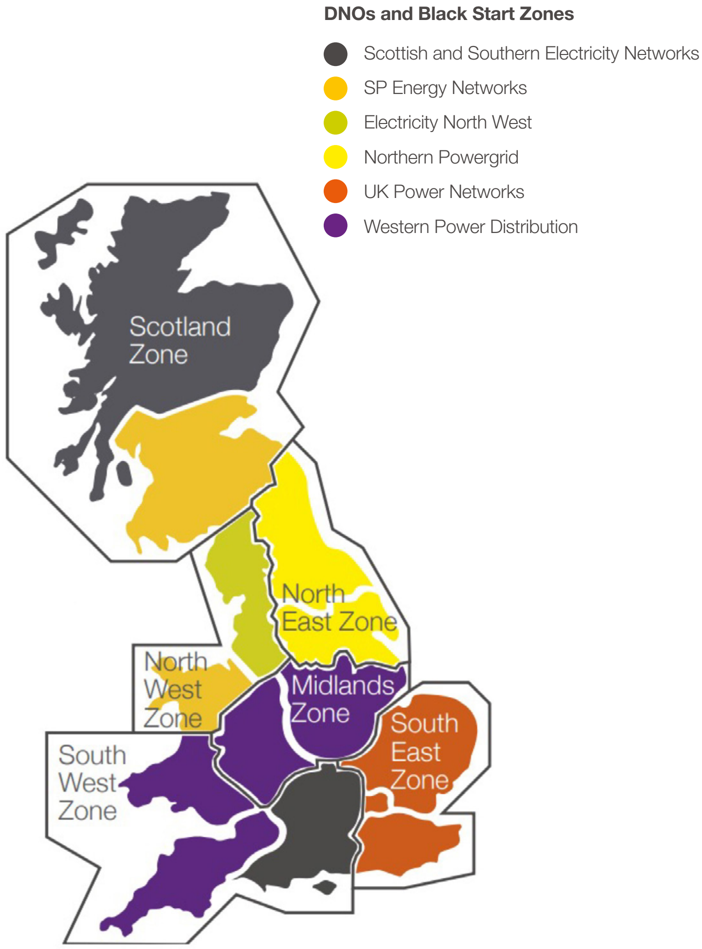


Figure 3: Map depicting the DNO licence areas and the responsible company. Black lines indicate the Black Start procurement zones as annotated

1.4 Key Concepts for Distribution Level Restoration

1.4.1 Organisations Involved

National Grid Electricity System Operator (NGESO) is the company responsible for the efficient operation of Great Britain's National Electricity Transmission System (NETS) and all directly connected assets. Under normal operations, it has strategic control of the electricity transmission system and may issue instructions but does not enact physical switching, except where automatic processes are pre-agreed with the relevant party. Under a Black Start scenario, NGESO assumes overall control of the event with the Power System Manager from its Electricity National Control Centre (ENCC) becoming the overall Black Start controller. NGESO is responsible for the provision and assurance of the overall Black Start service before the event as part of its licence and Grid Code obligations. Local joint restoration plans (LJRPs) are developed by NGESO in conjunction with all other parties involved to define basic technical parameters and responsibilities in advance of a Black Start event.

Transmission owner (TO) is responsible for building, maintaining and operational switching of the NETS. The transmission system includes all circuits which operate at 400kV or 275kV in England and Wales. In Scotland, 132kV is also a transmission voltage level. There are three companies which have responsibility for this in Great Britain: National Grid Electricity Transmission (NGET) in England and Wales, SP Transmission PLC (SPT) in Central and Southern Scotland, and Scottish Hydro Electric Transmission Ltd (SHETL) in Northern Scotland.

Distribution network owner (DNO) is responsible for building, maintaining and operating the distribution network within their distribution network licence area. The distribution network covers all circuits from 132kV and below in England and Wales and 33kV and below in Scotland. There are 14 DNO licence areas covered by 6 different companies.

Distributed energy resource (DER) is any form of energy resource (inclusive of batteries and other energy storage resources) installed on the distribution network rather than the transmission network. There is no specific size requirement for the project to consider an energy source as a DER.

Distribution restoration zone (DRZ) – a distribution restoration zone (DRZ) contains all assets and DERs which are located within a predefined distribution network area and include transmission network synchronisation point(s). These assets collectively provide a transmission level service which could include outward energisation or may only restore local energy supplies until re-synchronisation to the wider system can be achieved.

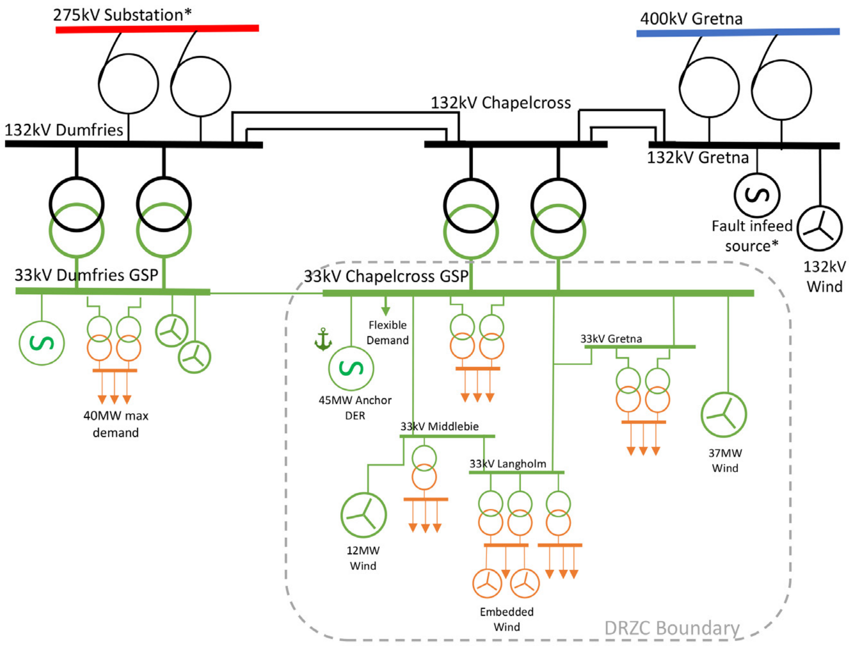


Figure 4: Diagram showing an example DRZ boundary; note that this is illustrative only

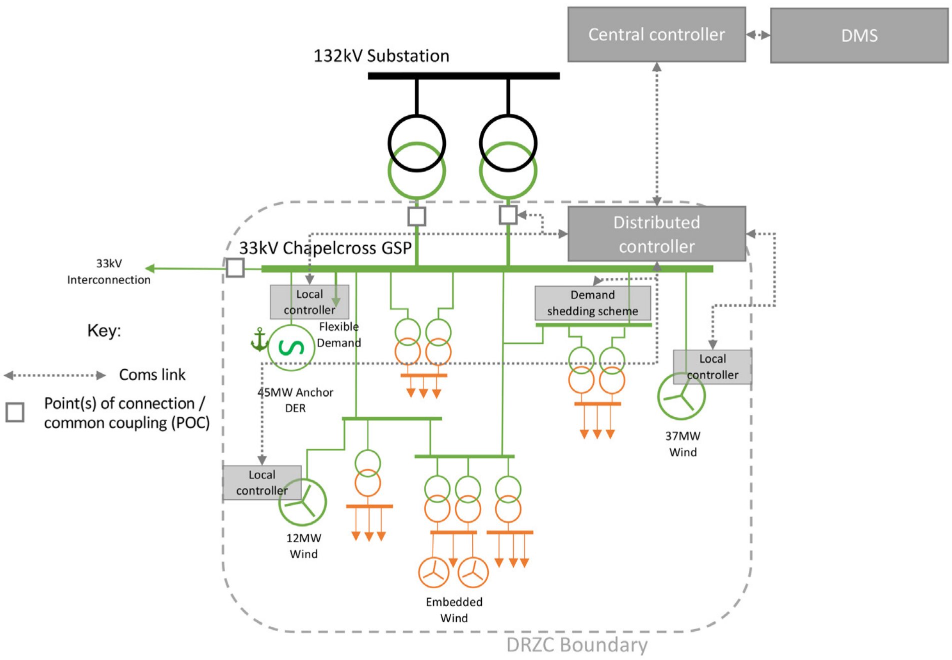


Figure 5: Conceptual DRZ-C architecture

1.4.2 Distribution Restoration Zone Controller

The distribution restoration zone controller (DRZ-C) is an automated control scheme that will reside in the distribution network operator (DNO) network. The objective of this control scheme is to establish a power island with an appropriate workflow to enable initial energisation, connection and dispatch of distributed energy resources (DERs), and restoration of local demand. Once the power island is established, the goal would be to harness the collective capabilities of the anchor DERs, other DERs providing support services and flexible demand to maintain stability and possibly provide an aggregate capability at the point of connection to support wider network restoration.

2 Electricity System Restoration Standard

The Electricity System Restoration Standard provides a new target for speed of demand restoration. Distributed ReStart has the potential to support delivering against this requirement.

2.1 Introduction – the current arrangement

The Black Start Strategy and Procurement Methodology (version 5.0 2021/22) is a yearly publication used to guide National Grid Electricity System Operator (NGESO) on the requirements and existing capabilities for electricity restoration in the event of partial or total power outage. NGESO determines the required system restoration capability for GB nationally and regionally, and reviews options for procuring additional capability or extending existing capability. NGESO is obligated to provide an expectation of the time required to restore the National Electricity Transmission System (NETS) following a Black Start event and to describe NGESO's approach to meeting that restoration time. NGESO is expected to inform Department for Business, Energy and Industrial Strategy (BEIS) and Ofgem where it cannot meet this expected time (minimum service level) due to extreme or unforeseen circumstances. NGESO has to demonstrate the actions it has taken to reduce the impact to system restoration and detail the changes being proposed to the level of provision.

NGESO applies the strategy and planning assumptions based on historical capabilities and a detailed statistical model and aims to achieve restoration of 60 per cent of national demand within 24 hours, or where this is forecast not to be met, procure additional service providers. There may be regional variations to this restoration time, and the aim is to create a broadly consistent rate of restoration nationally, reflecting the regional nature of civil contingency planning. In real time, a warming strategy is used to ensure that this procured capability is maintained in a state of readiness where the market would not otherwise lead to this generation running.

NGESO is required to demonstrate that this procurement and warming strategy is economically efficient and is subject to an annual efficiency check on its expenditure. This follows a cost pass through methodology to enable contracting with required resources to deliver against the Black Start Strategy and Procurement Methodology.

Calculation of the Restoration Time requires a probabilistic assessment of shutdown scenarios, reflecting the range of severity of events, to determine likely timescales for differing stages of restoration. The selected Restoration Time is a balance between a realistically achievable level of network energisation versus an economic level of service provision.

2.2 Electricity System Restoration Standard

BEIS, in consultation with industry partners, the devolved administrations and the energy regulator Ofgem, released a Policy Statement (Introducing a new 'Electricity System Restoration Standard': policy statement – GOV.UK (www.gov.uk)) setting out the need to strengthen the current regulatory framework by introducing a legally binding target for the restoration of electricity supplies in the event of a NETS failure. The new policy will be called the Electricity System Restoration Standard (ESRS). Ofgem launched a consultation on its proposed modifications to the Electricity System Operator's licence condition to create the power for the BEIS Secretary of State to set a new ESRS. As a result, NGESO's licence condition will change in October 2021. BEIS and the Secretary of State has issued a legal direction to NGESO requiring it to comply with the ESRS no later than 31 December 2026.

BEIS, in stating the rationale for a new standard, highlighted that the minimum service level currently maintained by NGESO is an internally defined target based upon the results of NGESO's probabilistic modelling rather than a holistic assessment of all possible consumer impacts of an outage. BEIS have identified a possible discrepancy between NGESO's current restoration capabilities and the consumer benefits of a restoration. Furthermore, the disconnect is "likely to become more pronounced as the electricity system continues to decarbonise and decentralise, and as society's and industry's dependence on electricity continues to grow". For this reason, BEIS have proposed that the responsibility for determining the appropriate restoration time is better placed with the government.

This new ESRS would replace the standards set by NGESO in the existing Black Start Strategy and Procurement Methodology with a clearly defined restoration target based upon an economic model of consumer benefits. This will require a robust assurance framework which enables NGESO to demonstrate, through training, assurance and testing, compliance of the whole industry against the restoration standard set by BEIS.

It is expected that this standard will require NGESO to have sufficient capability and arrangements in place to restore 100 per cent of Great Britain's electricity demand within 5 days. It should be implemented regionally, with an interim target of 60 per cent of regional demand to be restored within 24 hours. The Electricity System Restoration Standard (ESRS) is intended to reduce restoration time across Great Britain and ensure a consistent approach across all regions.

The outcome of this requirement is that there will be a need for more restoration service providers to enter the market by 2026. This is a driver for including distribution level restoration options within the overall procurement framework and demonstrates the importance of this project to ensuring a competitive environment for electricity system restoration capability across GB.

2.3 Role of Distributed ReStart in the Electricity System Restoration Standard

The ESRS represents a step change in requirements for restoration. In contrast to the Black Start Strategy and Procurement Methodology, which aims to restore 60 per cent of demand nationally under average network conditions, the new standard requires 60 per cent restoration capability in all regions under reasonable worst-case network conditions. The incorporation of distribution restoration zone plans (DRZPs) into the overall restoration strategy will support this more onerous requirement being met and is a key driver for further efficiencies compared to the manual process presented in the initial design.
The introduction of a distribution restoration zone controller (DRZ-C) in the distribution network operator (DNO) network will contribute to meeting the regional restoration target by enhancing restoration timescales and allowing for regions with fewer transmission connected resources to be directly fed by local generation. This results in a number of different options for utilisation of a DRZ within the national strategy which are set out in this chapter.

The current traditional transmission restoration approach uses several self-starting service providers to energise pre-agreed local joint restoration plans (LJRPs), create a power island and restore demand. Distribution level restoration will use the concept of a distribution restoration zone (DRZ) building a power island that consists of both demand and co-located generators to deliver outward energisation, or support regional demand restoration. The number of LJRPs and DRZs that each transmission network owner (TO), distribution network operator (DNO) and distributed energy resources (DERs) area can carry out at any one time should be continually reviewed to assess capabilities to meet the standard for the respective restoration zones.

The planned communication interface in Figure 6 below depicts communication flow when the LJRP and DRZ plans are enacted in tandem, and the process design delivered in this report is considered as a complementary capability to existing procedures rather than an entirely new process to be delivered independently.

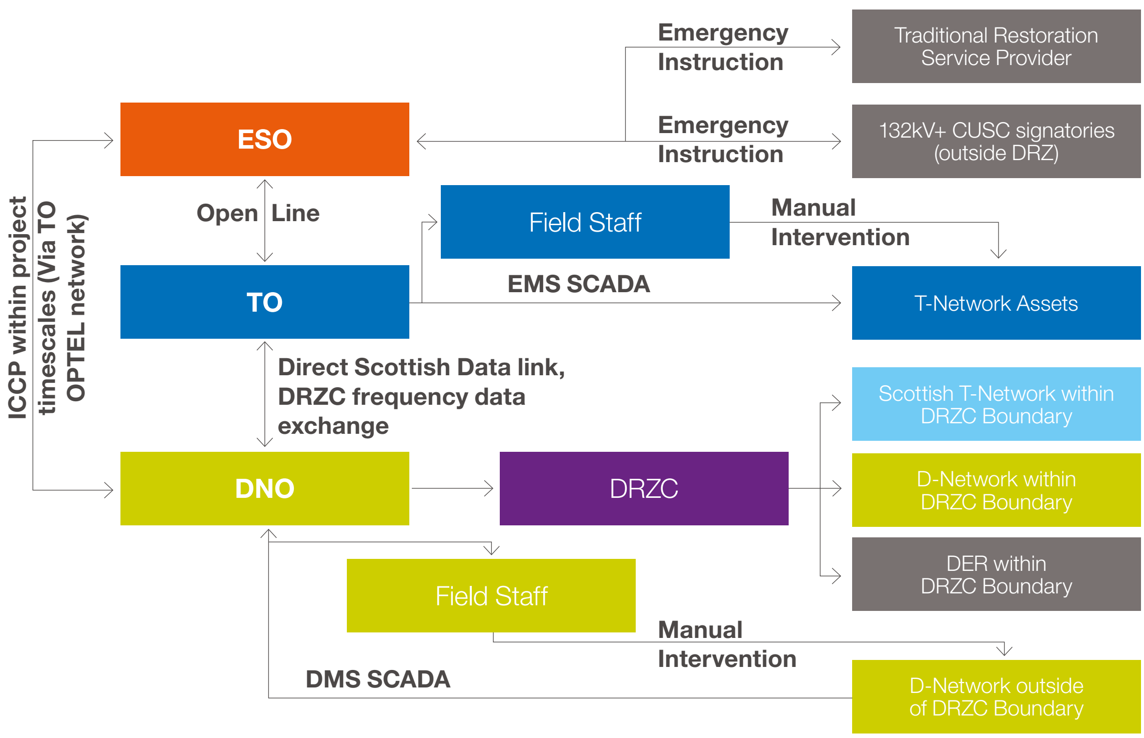


Figure 6: LJRP and DRZ plans joint communication interface

2.4 Options within Distribution Restoration when Creating a Plan

The use of automation in distribution restoration has been identified as a key aspect of implementing an effective organisational process, as the number of utilised distributed energy resources (DERs) increases. It would be difficult to coordinate the restoration process manually involving so many DERs and the consequential balancing actions. The use of the distributed restoration zone controller (DRZ-C) in the distribution network operator's (DNO) network within a distributed restoration zone (DRZ) will enhance restoration timelines on a local level under all scenarios but can have different end objectives to best deliver against the overall regional requirement when considering that these will be implemented in parallel with conventional local joint restoration plans (LJRPs).

There are different possible DRZ restoration routes identified, and these routes and order of preference should be pre-agreed in the plan. The restoration route choice will vary for the specific combination of network and resources, and these will be identified as part of a feasibility analysis within initial zone procurement, and continually reviewed through assurance activities. These options will depend on individual site studies and be subject to meeting specific criteria such as minimum fault levels. The emphasis on the defined strategy should be meeting the Electricity System Restoration Standard (ESRS) timeline target and should consider LJRPs or distribution restoration zone plans (DRZPs) that may exist in the area.

Under all restoration sequences, the DRZ is established using the self-starting 'anchor DER', which is used to energise primary substations and DERs within the local network area. It is then possible for expansion of this power island through use of various methods including:

- **Option 1:** Local network growth only
- **Option 2:** Distribution level network growth
- **Option 3:** Synchronisation of a parallel DRZ
- **Option 4:** Distribution network growth via the transmission network
- **Option 5:** Inclusion of a transmission connected resource within the DRZ
- **Option 6:** Skeleton network growth fed by the DRZ with synchronisation at transmission level.

Through using the Chapelcross case study, these options are illustrated below. However, all of these options support the goal of regional demand restoration, and the technically optimal option will depend on the specific local demand and local energy resources. This additional flexibility of DRZ procedures allows them to be used for the specific regional needs introduced through the restoration standard.

2.4.1 Option 1:

Maintain the DRZ with maximum stable load connected and do nothing else. Synchronise with the transmission network at 33kV once energised. This will support the demand restoration target within the region through local demand restoration over a shorter timescale. Where this can independently maintain supplies, it can provide resilience to more remote areas while waiting for the wider transmission network to be restored. This features in process design as a break point.

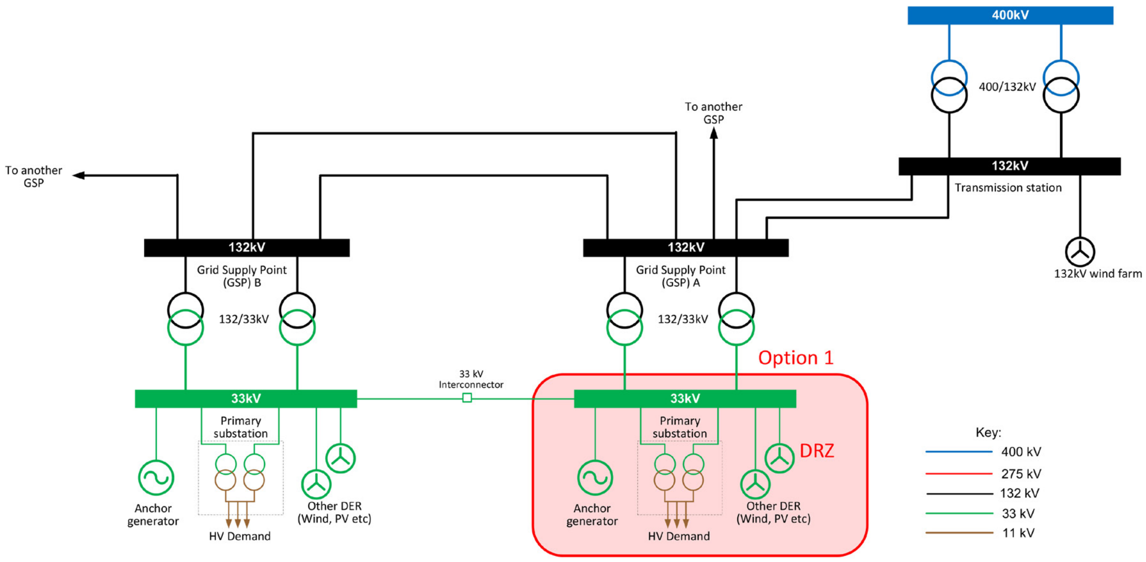


Figure 7: Option 1 restoration strategy

2.4.2 Option 2:

Expand the 33kV distribution restoration zone (DRZ) to an adjacent 33kV network via interconnecting 33kV circuits and connect additional distributed energy resources (DERs) and pick-up demand (Limiting factor = 20MVA transfer capacity). This option would allow interconnection at distribution level to expand outside of the pre-determined DRZ network area to feed additional local demand. This is advantageous even where supply does not meet all demand as you could feed critical local demands while waiting for transmission network energisation across a wider area. Additionally, if the energy supply in the network area exceeds the demand requirements, this would allow excess supply to meet demand without requiring transmission access if transmission network owner (TO) resources are constrained by a local joint restoration plan (LJRP). However, this option is limited by the limited energy transfer capability typically found on these interconnections.

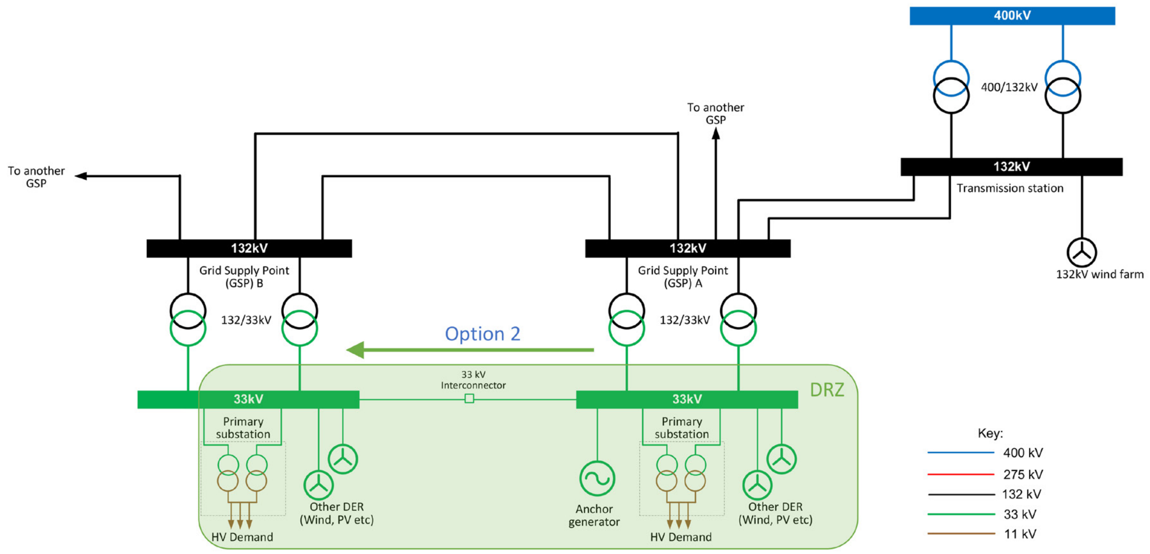


Figure 8: Option 2 restoration strategy

2.4.3 Option 3:

Expand the 33kV DRZ by synchronising to an adjacent 33kV DRZ through 33kV interconnector to create a single larger power island. (Limiting factor = 20MVA transfer capacity). This option would enable parallel DRZs to be synchronised at distribution level improving the resilience of supply through interconnection. This process is not specifically captured under the process design as it is less likely that this will be an option in early stages of procurement for distribution restoration where geographic diversity is advantageous due to the limited number of plans available. Should this be an option, the synchronisation function in the DRZ-C would enable this as part of further distribution power island growth without reference to National Grid Electricity System Operator (NGESO).

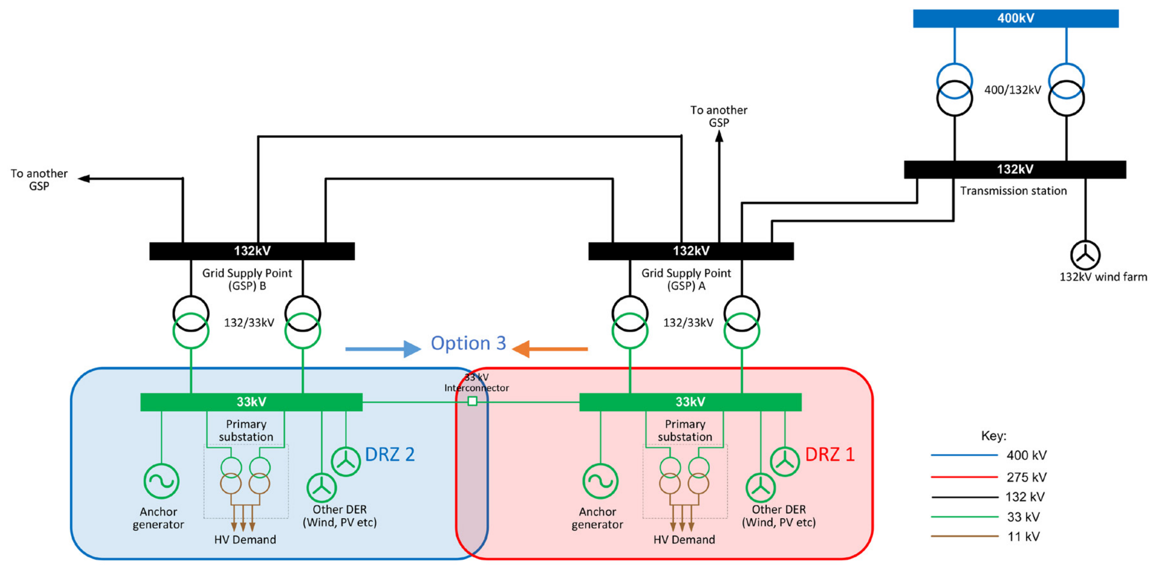


Figure 9: Option 3 restoration strategy

2.4.4 Option 4:

Expand the 33kV distribution restoration zone (DRZ) by energising one of the 132/33kV grid transformers and then an adjacent 132/33kV substation. Energise the adjacent GSP from the 132kV down to 33kV and pick up more demand and distributed energy resources (DERs). This option would allow for further demand to be fed from the DRZ without limiting the energy transfer to the interconnection capacity. This features under the restoration option of continued distribution level growth post transmission energisation in the process design.

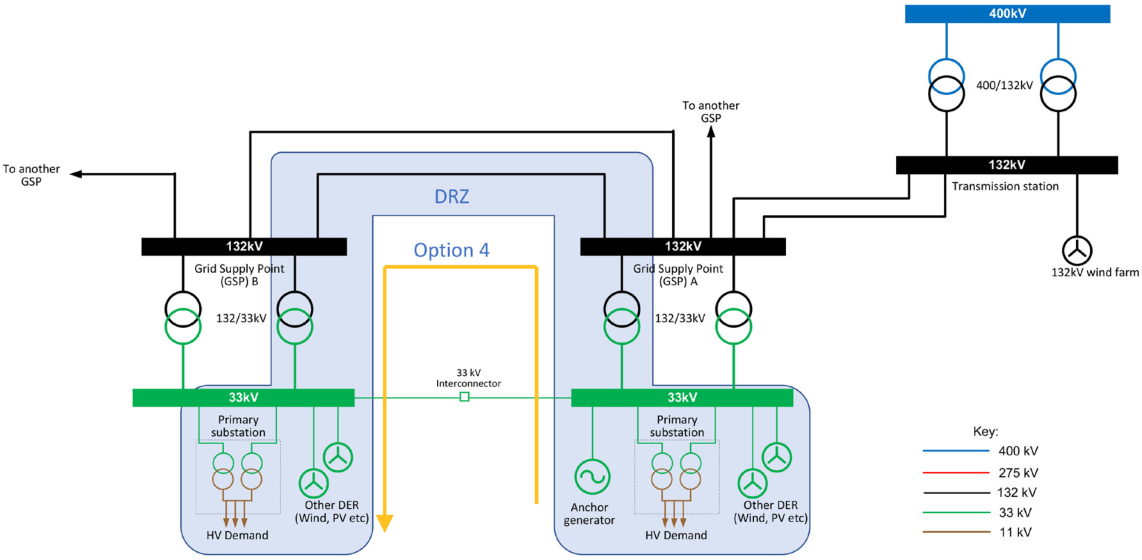


Figure 10: Option 4 restoration strategy

2.4.5 Option 5:

Expand the 33kV distribution restoration zone (DRZ) by energising one of the 132/33kV grid transformers and then energising a 132kV circuit to connect additional generation connected at 132kV level. Pick up 33kV load. Connection of a transmission level resource was the focus of our desktop exercise; by introducing this concept of a distribution network operator (DNO) controlled energy resource connected at transmission level, we have been able to appropriately adapt the process design and gather control engineer feedback.

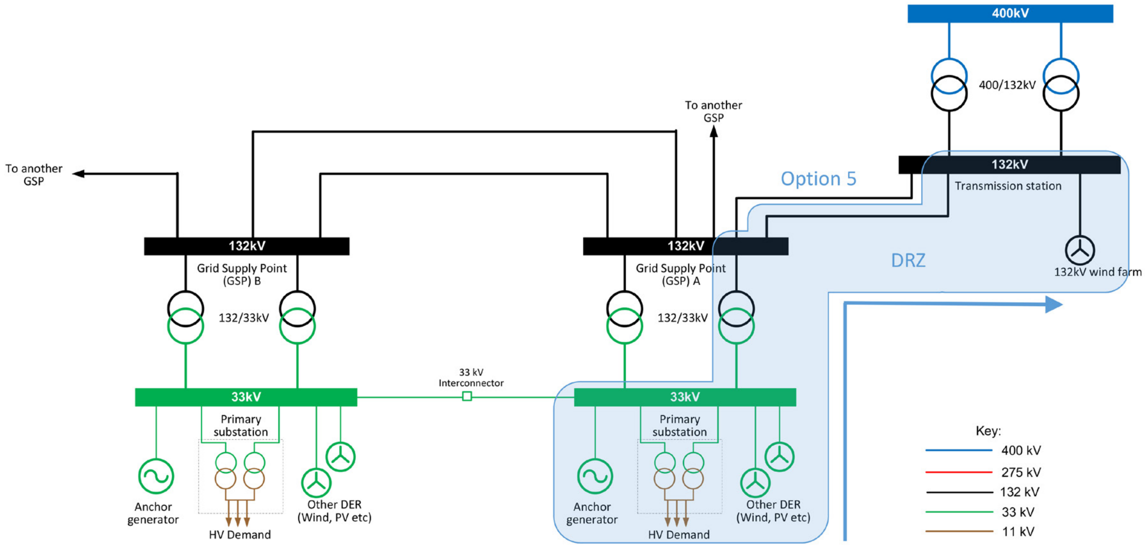


Figure 11: Option 5 restoration strategy

2.4.6 Option 6:

Expand the 33kV DRZ by energising one of the 132/33kV grid transformers. Expand the 132kV network to energise a 132kV connected fault infeed source, and then energise the 400kV (or 275kV) transmission network. This option allows for energisation of the wider transmission network through energisation up to 400kV. The process design has been adapted to enable this sequence of energisation through transmission network energisation prior to completion of the distribution level plan. It may be advantageous to energise this network ahead of any load to prevent passing on voltage dips to consumers, but the technical risk would be assessed as part of the development of a restoration zone plan.

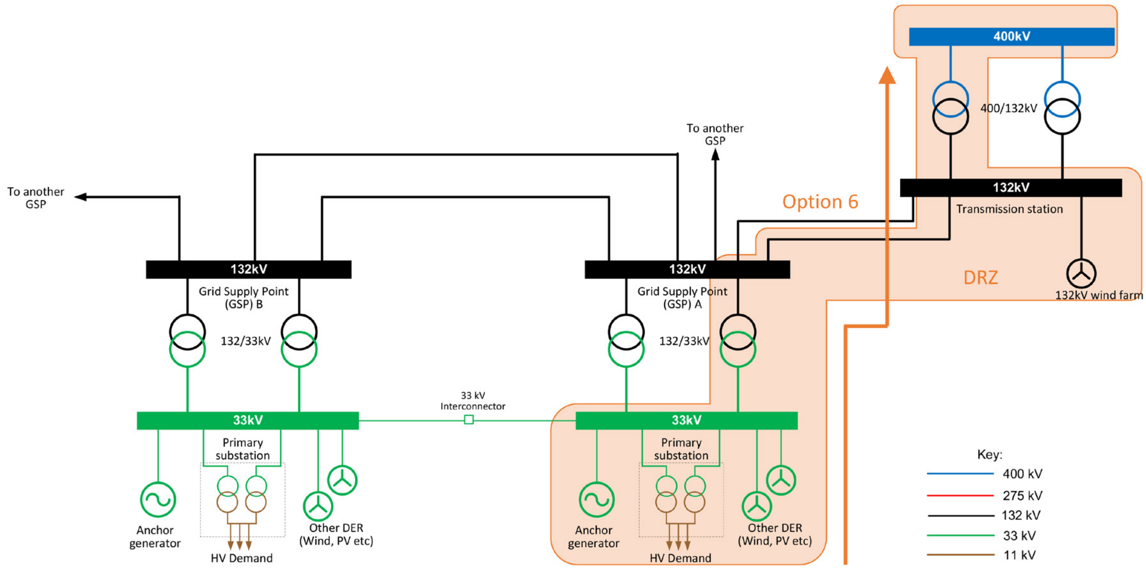


Figure 12: Option 6 restoration strategy

2.5 Conclusion

The Electricity System Restoration Standard (ESRS), once implemented, will set new targets on timelines and regional capability for demand restoration in GB. Implementation of the ESRS will lead to licence modifications for compliance with the standard. As a result, new frameworks for robust monitoring and management of compliance with the standard will be developed. The standard will require National Grid Electricity System Operator (NGESO) to have sufficient capability, people and processes in place to restore 100 per cent of Great Britain's electricity demand within 5 days. It will require that this objective is implemented regionally, with an interim target of 60 per cent of regional demand to be restored within 24 hours.

The concept of bottom-up restoration will help in delivering against the regional restoration target within the ESRS, and the options presented all support this objective where they can be synchronised to the NETS. A coordinated approach using both local joint restoration plans (LJRPs) and distribution restoration zone plans (DRZPs) will be critical for achieving the ESRS target. For this reason, DRZPs should be assumed to be introduced in parallel with conventional LJRPs and collectively be used to meet new ESRS targets.

The reasons that different restoration options would be used will be based on system studies and alignment with regional and national demands. The chosen option(s) would be pre-agreed within the restoration plans and the routes arranged in preference order.

3 Stakeholder Engagement

The input of stakeholders has been integral to the process and organisational development. Engagement has been conducted with every network operator in GB and multiple distributed energy resources (DERs) types to test our design.

3.1 Introduction

Stakeholder engagement has been a critical element of refining our organisational and process designs to work for end users. We have ensured that every GB network company has been directly engaged and consulted with during this refine stage. This helped develop an understanding of the challenges in applying this methodology GB-wide and has enabled change requirements to be captured and documented. Furthermore, multiple content distribution methods have been used, and analysis of stakeholder interaction across these different media types has been applied in order to ensure we reach as wide a stakeholder group as possible, both to provide awareness and to incorporate valuable feedback.

Across the refine stage we have presented at internal and external webinars; we have utilised podcasts, videos and other multimedia content; and we have developed a custom simulation environment to encourage active participation and stakeholder interest. This enables our design to be co-created with the audience and be applicable to as many energy resource types and network operators as possible. However, this process will continue to develop and change as it is adopted into business processes and each individual operator adapts it to meet their systems. For this reason, all direct feedback and questions have been captured to ensure it is not lost across roll-out. This can be found in Appendix 1: Stakeholder Questions.

Across the refine stage we have continued to grow our active distribution list to over 720 registered interested parties and used this as a channel to engage with people globally through email updates, webinars, virtual events, podcasts and live demonstration stimulation to share pertinent project information.

3.2 Distributed ReStart Podcasts

The podcasts were designed to incorporate all workstream outputs and to present the project's journey through a series of challenging questions posed both to internal project members and external industry experts. The podcasts remain hosted on Spotify, which extends our global reach beyond direct contacts we are likely to make through standard industry channels, and remain available for stream and download. We believe that by trialling many different communication methods across the project, we will reach the broadest possible audience because everyone in GB has a vested interest in electricity restoration and should have the opportunity to interact with the content. The focus of the Organisational, Systems and Telecommunications podcast (Podcast 5) was to explore the work being done on cyber-security, systems, telecommunications and the procedural changes that drive these new technical requirements. While this report focuses on the organisational and procedural refine stage outcomes, the findings in these key supporting topic areas will be delivered as part of a report focused on distribution restoration zone controller (DRZ-C) implementation due for publication February 2022.

3.3 Desktop Exercises

To validate the efficacy of the organisational proposal, a series of simulated restoration events in the form of desktop exercises were conducted with representatives and control room engineers from each of the main stakeholder categories, inclusive of all GB network licensees and operators of most major DER technology types. They involved simulation of an electricity restoration event on the Chapelcross case study network area.

The restoration scenario in the exercises used 33kV connected distributed energy resources (DERs) to restore a 33kV distribution network, perform energisation of a 132kV circuit to another transmission station, and energise a 132kV connected wind farm and a 400/132kV transformer before restoring demand to the 33/11kV primary substations in the network.

The desktop exercises were facilitated through a custom-developed, web-based simulation tool, providing a graphical user interface, with a representative single line diagram view of the distribution and transmission networks as seen by National Grid Electricity System Operator (NGESO), transmission network owner (TOs), distribution network operators (DNOs) and distributed energy resources (DER) control room engineers on their respective network management systems. Participants were able to switch circuit breakers to advance the restoration in accordance with the network restoration plan, and measurements were dynamically updated on-screen, using values that were obtained during extensive steady state and dynamic power system studies to provide a realistic user experience. The desktop exercises were each carefully observed to gain maximum learning on the effectiveness and robustness of the proposed organisational and communications model, and possible improvements were identified.

Three desktop exercises were hosted across a three-month period to ensure that the opportunity for participation was maximised. This resulted in reaching every GB network operator through the exercises, ensuring control room views were captured and promoting greater awareness within organisations. The outputs from these exercises were disseminated for challenge and review by leading academics through the National Grid Electricity System Operator (NGESO) Engineering Advisory Council (EAC) for further scrutiny.

Our desktop exercises used hands-on experience to promote awareness and gather feedback from control engineers currently responsible for network restoration and potential future service providers.

The exercises were conducted virtually, reaching over 120 unique participants across all GB network operators, 20 different businesses representing future service providers and 8 leading academic or consultancy interested parties. This broad reach provides confidence in the procedural design for future GB roll-out and has drawn out many improvements discussed in Chapter 4. A full documentation of all questions and answers is provided in Appendix 1: Stakeholder Questions.
The campaign video for the desktop exercise can be viewed via the link: **bcove.video/2VyI2v8**

3.4 Engineering Advisory Council

Post-delivery of desktop exercises, the project put the outputs of the procedural design, including identified improvements, up for challenge and review by NGESO's EAC function ensuring that an external review has been provided to complement operational experience with robust critical analysis. A briefing report, presentation and extensive questioning has resulted in further improvements being implemented into the process design, and a record of all the questions is included in Appendix 1: Stakeholder Questions. The changes that we have made in response to EAC feedback are documented in Chapter 4.

3.5 Stakeholder Review and Challenge

The Organisational, Systems & Telecoms (OST) workstream has taken part in numerous targeted industry consultations inclusive of membership of working groups and hosting workshops. This allows direct input to project deliverables drawing on knowledge of subject matter experts inclusive of rigorous challenge. See Table 1 below.

Table 1: Stakeholder engagement

Event	Value Unlocked
NGESO Network Control, Regional Development and Balancing Programmes	Knowledge share between NGESO programmes to provide a whole system approach view where the activities and objectives align – exchange of data, voice communication and systems integration requirements.
Cyber security workshops with DERs and DNOs	Workshop with various organisations' cyber teams to understand the current practice, gaps and the development of the Distributed Re-Start cyber security functional requirements.
Phasor Measurement data share – National Grid Electricity Transmission (NGET)	Engagement to facilitate a new requirement for exchange of phasor measurement data between DNO and TOs for the distribution restoration zone controller (DRZ-C) development.
Engagement with Ofcom	Engagement to provide Distributed ReStart project update and view from Ofcom.
Regional Development Programme distribution network operator (DNO) forum	Presentation of the distribution restoration zone (DRZ) functionality to the forum and eliciting discussion on potential interaction with other systems in each DNO's network.
Project engagement with SSE RaaS project	Project collaborations to explore areas of cooperation and learnings.
Project engagement SGN – Gas Distribution	Project engagement with gas network operators looking at Black Start requirements.
Project engagement with telecoms suppliers	Discussion and collaborations on requirement for resilient telecoms infrastructure for Black Start.
Organisational process map presentation to National Grid Electricity System Operator (NGESO) stakeholder forum – Engineering Advisory Council	Present the Distributed ReStart process map and solicit expert feed-back from industry experts and academia.

4 Refine Stage Outputs

The refine stage has built on outputs from the process design, adopting a continuous improvement cycle based on feedback and cross-project findings.

4.1 Desktop Exercise Simulator

4.1.1 Simulation Requirements

The primary aim of the desktop exercises was to test the communication interfaces, visibility requirements, task allocation between the stakeholders and sequence of actions proposed in the Distributed ReStart organisational design and communications process.

The simulation tool was conceived to support the desktop exercises, its main purpose being to emulate the control room environments for the different stakeholders, providing a 'real-time' view of the electrical network under their control, and enabling them to perform switching actions on the distribution and transmission network to restore power supply.

This exercise followed the manual procedure but did not introduce a requirement for balancing or frequency management. This is reflective of the expected distribution restoration zone controller (DRZ-C) fast and slow balancing functionality that should limit direct control engineer input.

Role play was incorporated to capture what it would be like in real-life scenarios with automation, and hence there are limitations in that it may not capture every real-life event or situation that can occur.

4.1.2 Simulation Tool Development

Background

The Chapelcross GSP network was one of the three case study networks that were studied in detail as part of the Power Engineering and Trials (PET) workstream in 2020. This involved detailed steady state and dynamic power system studies that led to the development of several viable restoration scenarios. One of the restoration scenarios (Option 6) was selected for the desktop exercise because it involved restoration of the 33kV distribution network as well as parts of the 132kV and 400kV transmission network, thereby requiring interaction and coordination between all the Distributed ReStart stakeholders, namely National Grid Electricity System Operator (NGESO), transmission network owner (TO), distribution network operator (DNO) and distributed energy resource (DER) control engineers.

Functional Design

Several platforms were considered to host the simulation, with the final decision being a custom-developed, web-based solution that could be accessed from anywhere without requiring the participants to install any special software. The functional requirements included the following features:

- They enable the participation of multiple stakeholders from each of the stakeholder groups, i.e. NGESO, TOs, DNOs and DERs, and give them visibility and control only over their 'own' networks and assets.
- There is provision for an 'observer' role to have an overview of the switching actions of all the other participants.
- The network single lines and operating views displayed on the tool needed to replicate as far as possible the control centre operating displays seen by NGESO, TO – (Scottish Power Transmission (SPT)), the DNO – (SP Energy Networks (SPEN)) and DER control engineers. This includes breaker and switch statuses, colouring of lines to indicate energised or unknown status, and displaying key measurements such as voltage, current, MW and MVAr.
- Measurements displayed on the diagrams would be based on the load flow power system studies performed in 2020 using a look-up table, rather than real-time calculated values, and will be updated after each switching operation is performed.
- To limit the amount of development work, the simulation only needed to follow the pre-determined restoration script for Chapelcross Option 6. Participants would not be able to perform switching operations not contained in the script.
- There would be an option to add additional restoration scenarios, additional case study networks and contingencies at a later stage.

Development Process
The simulation tool was developed over a period of two to three months following a structured development process. This included a design and scoping phase during which the front-end of the tool including the menu options and single line diagrams (SLDs) were discussed and agreed with representatives from SP Energy Networks (SPEN) (as distribution network operator (DNO) and transmission network owner (TO)), National Grid Electricity System Operator (NGESO) (as electricity system operator (ESO)) and National Grid Electricity Transmission (NGET) (as TO).

This was followed by the development and coding phase that included:

- development of the back-end system, e.g. user login, page navigation, simulation database, synchronisation of the database, server configuration
- development of the front-end, which included generation of the different single line diagram (SLD) views, implementation of the restoration scenario, development of look-up tables for parameters, display of parameters, coordination of control by participants.

The testing and customisation phase included internal testing (modular testing and system testing), followed by beta-testing with the project stakeholders. Through the testing process the tool was debugged and further enhanced and customised to improve end-user experience.

A user manual was developed that explained the process of logging onto the simulation tool, navigation using the different menu options and the steps required to progress the restoration process during the simulation.

4.1.3 Implementation and Functionality

The simulation tool has been developed to emulate typical control system software as seen by system restoration engineers. Users can progress a pre-defined restoration scenario from a dead network state to full system restoration by means of closing various breakers and incrementing generator output. To capture valuable learning from the desktop exercises, the tool was made available through the public domain, as a browser-based application, via the Internet.

Our approach to providing an intuitive and efficient tool was mostly implemented with Python and JavaScript, two core technologies in web application development. This comprised two distinct modes of implementation: front-end development – design of the graphical user interface, widget control methods and feedback functionality; and back-end development – including server communications, data processing and client connection management.

Front-End
The simulation tool has been developed as an easy-to-use platform which provides key stakeholders with a clear understanding of the necessary actions involved in a Distributed ReStart scenario. The figure below shows the proposed layout of the tool as a sitemap.

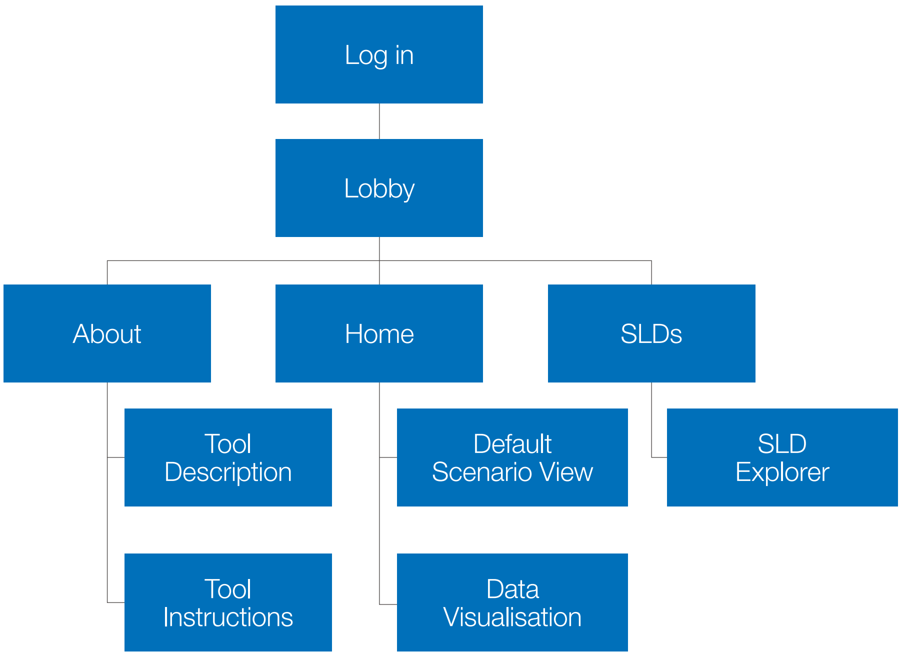


Figure 13: Desktop Studies Simulation Tool Sitemap

The tool's graphical user interface is supported by binding Python frameworks for building web analytic applications, such as Dash, with custom features built with JavaScript, a dynamic programming language for building unique interactivity into web-based platforms. Development of the custom user interface, such as the control system emulator at the tool's core, was made possible with the capabilities of JavaScript.

More generally, the structure of the tool's navigations system features and optionality are implemented using Python frameworks which use a combination of HTML, CSS and JavaScript at its core. This functionality is typically processed client-side; however, to support the unique interaction among simulation participants and hosting through the public domain, various sets of accompanying technologies were required to support the back-end of the tool.

Back-End

The simulation tool required to operate fundamental data processes: user credential management, whereby only permitted users may access the tool and these credentials will dictate the perspective displayed from within the simulation tool; and simulation management, such that the progression of the live simulation remains synchronised among all active users. These processes were supported with the micro web framework for hosting web service gateway applications – Flask. The following figure describes the simple architecture for a multi-user system, deployed through the online web hosting service Heroku.

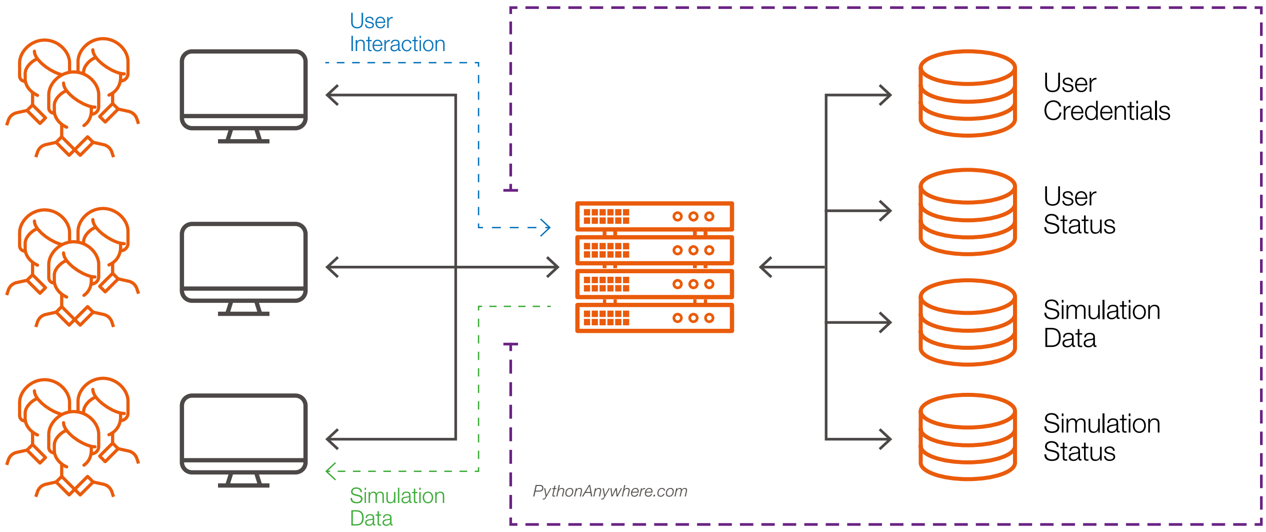


Figure 14: Multi-user architecture hosted on Heroku

Various asynchronous communications processes allowed for data management such as the login system and simulation synchronisation. Participants were granted access to the simulation tool through a secure login-based system, supported by Flask and a relational database management system, SQLite. Upon successful login, users were able to view both active and inactive participants before proceeding to the main simulation page. Through similar communications protocol, each user's local simulation status was synchronised in real time, capturing actions of participants across the various roles of the restoration scenario.

4.1.4 Running the Desktop Exercises

Prior to each of the three desktop exercises, the simulation tool was prepared and configured with a username and password for each of the participants that was used to identify and allocate them to the correct stakeholder group. A system administrator was on standby to assist with any login issues, to assist with any technical or performance issues and to manually progress the simulation if participants became stuck.

Once logged in, participants would be taken to a virtual lobby from where they were directed to the start of the simulation. Each of the stakeholder groups had the following access to the simulation:

Table 2: Single line diagram views

Stakeholder Group	Landing page	Single line views and control
National Grid Electricity System Operator (NGESO)	Chapelcross 132kV network SLD	Chapelcross 132kV, Gretna 400kV, Gretna 132kV, Chapelcross–Gretna 132kV circuits, Gretna–Ewe Hill 132kV circuit.
Transmission network owner (TO)	Chapelcross 132kV network SLD	Chapelcross 132kV, Gretna 400kV, Gretna 132kV, Chapelcross–Gretna 132kV circuits, Gretna–Ewe Hill 132kV circuit.
Distribution network operator (DNO)	Chapelcross 33kV network SLD	Chapelcross 33kV network.
Distributed energy resource (DER)	Steven's Croft anchor generator	Steven's Croft, Minsca WF, Ewe Hill 1 WF, Ewe Hill 2 WF.
Observer	Chapelcross 33kV SLD	All single line diagrams. The active single line diagram would always be displayed. No switching controls.

An example of the NGESO/TO view of the Chapelcross GSP 132kV network is displayed in Figure 15 while the DNO view of the Chapelcross GSP 33kV network is shown in Figure 16. The DER view of Steven's Croft Anchor generator is shown in Figure 17.

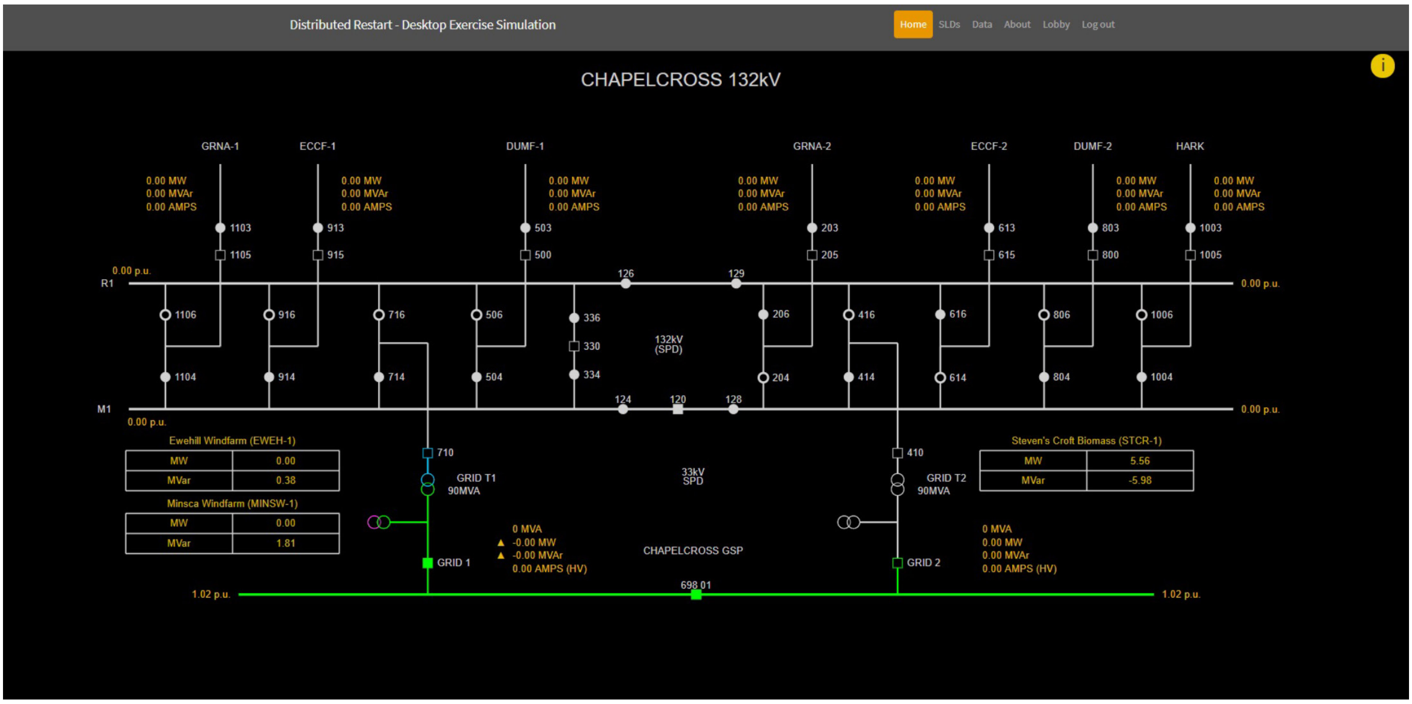


Figure 15: Overview of the Chapelcross GSP 132kV network seen by the NGESO and TO

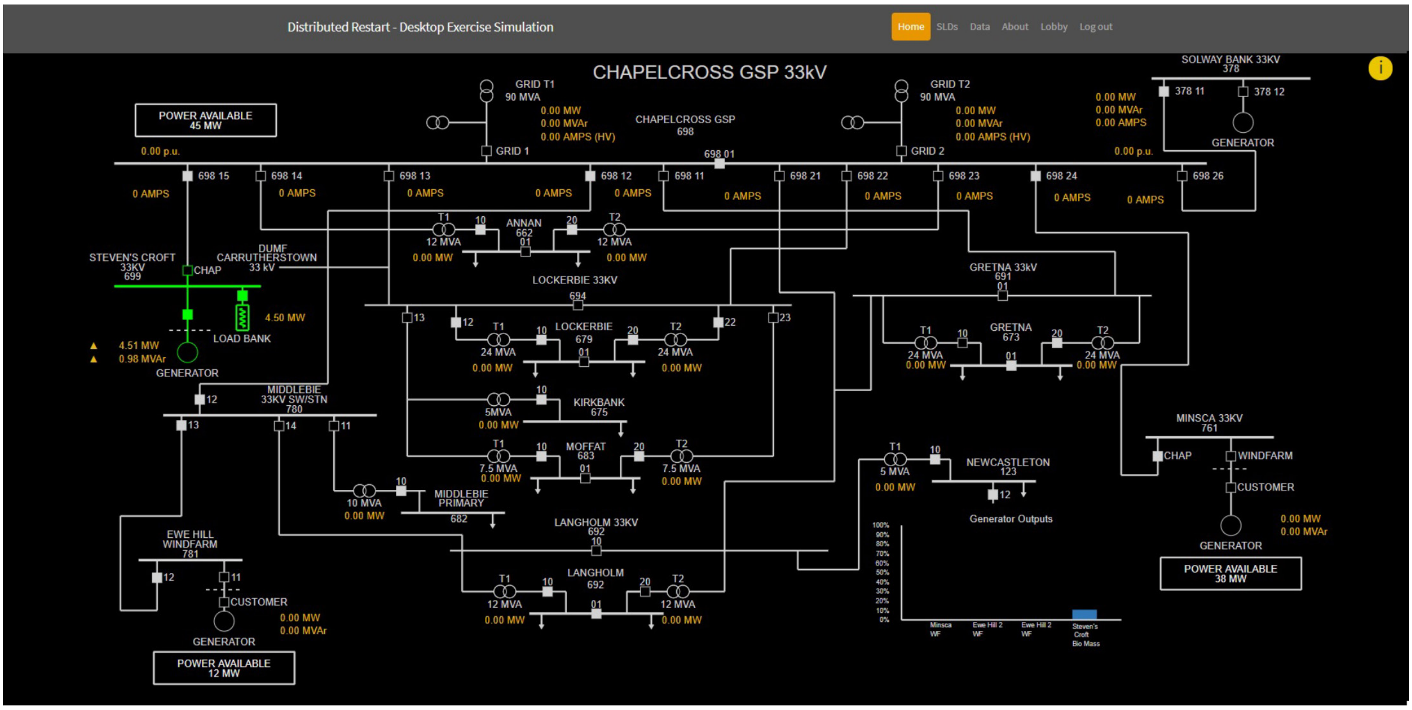


Figure 16: Overview of the Chapelcross GSP 33kV network seen by the DNO

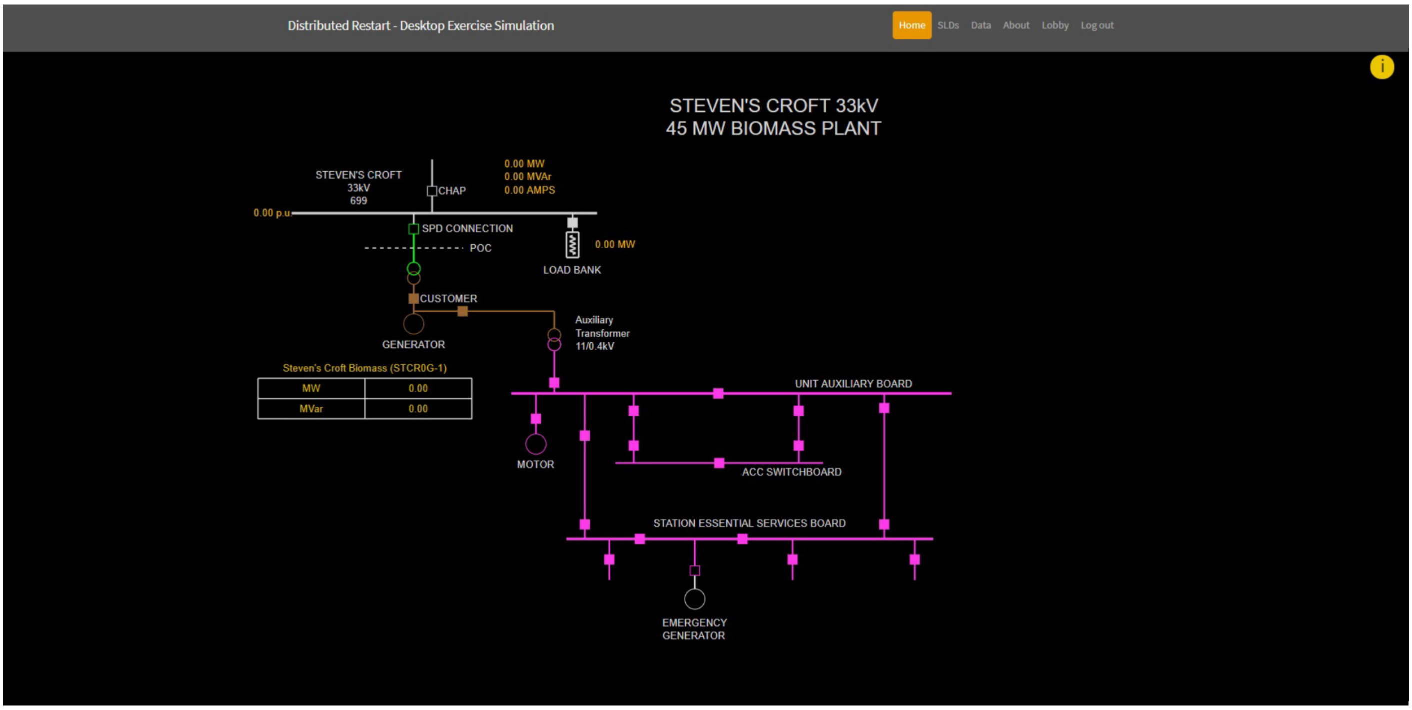


Figure 17: Overview of Steven's Croft Anchor Generator as seen by the distributed energy resource (DER) group

In some of the desktop exercises the stakeholder groups were quite large, consisting of between 10 and 30 participants. Unfortunately, it wasn't possible to give all participants the opportunity to perform switching actions to progress the simulation, and so only between one and four participants in each group were asked to progress the simulation, while the rest discussed the actions and assessed the communication and handover between the other stakeholders.

Some of the improvements made to the simulation tool between the first and last desktop exercise included:

- improvements to the login process
- performance improvements to the web server, enabling larger number of participants, and reducing the time to update diagrams and measurements
- adding charts that illustrate the DER MW outputs and the impact of cold load pickup on total demand and frequency stability for each of the restoration steps.

4.2 Learnings from Desktop Exercises

Across the three desktop exercises and Engineering Advisory Council review, we have established key learning themes which have fed directly into the new process design presented in Chapter 5. These are grouped in order to clearly show how they are addressed, but the questions posed are all included in Appendix 1: Stakeholder Questions.

4.2.1 Communications

It was clear from desktop exercises that communication was a key area of focus for further improvements both in clarity of communications, more specific requirements for data to be exchanged and a streamlining of some communications to reduce the operational burden.

Across both the desktop exercises and the engineering advisory council, it has been raised that it was possible that control engineers from different organisations could come away with a different understanding of what was agreed under highly pressurised scenarios. Distribution network operator (DNO), National Grid Electricity System Operator (NGESO) and transmission network owner (TO) control engineers go through rigorous training and authorisations in order to mitigate against this risk; this includes command and control language for instructing actions, and this is not a change introduced through restoration specifically. They should also leverage tools, such as logs, in order to ensure an accurate account of actions instructed (and repetition of instructions back to the other entity) to confirm a shared understanding.

The use of automation will also mitigate the risk, as this reduces the number of human instructions and manual tasks which can lead to misunderstanding. This enables standardised training across the participants where human instruction is required. It has been identified that after instruction of the start of a plan, NGESO does not need to be directly involved in operational approvals. This has been adopted in the new process map, which seeks to remove any non-essential communications steps. In particular, there is no need for a notification after the anchor DER is stabilised, and there is complete DNO autonomy to continue growth of the restoration plan within the pre-defined distribution restoration zone (DRZ) area even after transmission energisation.

It has been identified that NGESO needs a view of approximate information on time to DRZ completion, power available within the DRZ, the reactive capability of the DRZ and the state of charge/fuel for the DRZ for the purpose of sequencing. Approximate time to completion will need to be a distribution network operator (DNO) control engineer view based upon the resources available, but all other requirements have been captured as data points to be passed via the ICCP as part of a restoration procedure. This will provide a real-time view to reduce the communications burden but also create appropriate situational awareness for the business responsible for national strategy.

It has been raised that distributed energy resource (DER) control rooms may require remote monitoring and control of their assets from a central control room. The process has been designed to allow for manual or automatic response to distribution restoration zone controller (DRZ-C) signals which do not require low latency response (i.e. fast balancing), but any additional power resilient communications from the point of DER connection to the point of DER control will not fall under the functional telecommunications specification published by the project. However, power resilience of this internal communication (for the 72-hour specified communications timeline) would need to be assured if it is essential for delivery of the contracted service.

4.2.2 Sequence of Actions

The project was challenged on the preference of loading only a single point of demand while proceeding to connect more DERs. It was thought that this introduces a single point of failure to the procedure so may be a high-risk strategy. This proposal has been assessed and does not substantially reduce the level of risk as the anchor DER already represents a single point of failure. However, re-sequencing demand connection ahead of top-up service provider connection is more likely to lead to unacceptable voltage or frequency deviations being passed on to consumers. Therefore, we will not be changing the guidance for distribution restoration zone (DRZ) plan creation that energisation of DER should be prioritised before demand but do note that this specific risk should be considered when conducting feasibility studies on distribution network operator (DNO) switching options.

There is a requirement to issue a 0MW setpoint signal to a DER ahead of closing the DNO customer breaker in order to ensure they do not come on at full output when frequency and voltage is detected. However, DERs not contracted at 11kV or below are accepted as having an uncontrolled output seen as a reduction in demand and shall be considered when developing the block loading procedure for an individual DRZ plan.

4.2.3 Command and Control

In desktop exercises, we included the concept of a transmission connected wind farm forming part of the restoration zone with intent to understand the command and control issues which may be associated with this procedure. In a scenario where the transmission connected energy resource will become part of the DRZ, the instruction to join should come from the transmission network owner (TO) rather than the DNO. The DNO/DRZ-C will manage the voltage and frequency of the resource. The TO engineers at the exercise did not see this as an issue.

This case is only likely to occur in Scotland, where 132kV connected generation is transmission scale and there may be a requirement for 132kV connected fault infeed. However, the process has been adapted to enable continued DNO frequency control with connection of a transmission asset as long as it is contracted in advance to allow for this additional flexibility.

4.2.4 Timing

Top-up service providers may have a lead time after connection of auxiliaries before the service could be provided. This will be variable by technology type, but typical values raised in desktop exercises were up to 20 minutes. This has been considered within the process design, and the estimated time to connect a top-up service provider has been adjusted.

4.2.5 Data

Across desktop exercises it was identified that, dependent upon the wind farm technology type, wind farms may be able to provide full reactive range without any wind or may require a power available level in order to reach reactive capability. This leads to a possible new data point of reactive power available that would need to be captured in place of a static value through the DRZ-C.

Battery operators raised awareness of the importance of a state of charge signal feeding into our process design as this would affect the optimal positioning of DER across the group. This is a data point that can feed into the slow balancing response of the DRZ-C as this maintains headroom on conventional generators through distributing generation output, which is a similar concept to maintaining a state of charge that enables support of the power island.

These data points have fed into the automation design process, which is ongoing.

4.2.6 Robustness of the Operational Procedure

Desktop exercises did not consider the impact of the failure of the operational procedure and the automated system as they were intended to draw out issues with the procedural design in place of testing the control engineers. This means that the procedure may not be robust to failure and that control engineers have not been exposed to recovering from this. As part of the DRZ-C design, we have reviewed disaster recovery options which will enable continued operation of the DRZ-C against numerous failure modes including deliberate cyber and physical attack. Furthermore, future training will need to include failure modes in order to adequately prepare the control engineers for the uncertainties associated with restoration.

4.2.7 Options for Future Training Roll-out

The simulation tool proved effective during the desktop exercises, and feedback from the participants was positive. Direct feedback from desktop exercises suggested that the ability to conduct this training remotely in the future would be extremely beneficial, bringing savings of at least two days for all control engineers that would otherwise be forced to travel. Furthermore, more frequent training can be conducted at less operational burden. However, the current developed desktop exercise tool is intended for testing the procedure, rather than the control engineers, so requires alteration if planned to be used in this way.

The current implementation of the desktop simulation tool has been developed to reflect a single network restoration scenario, anticipating a limited number of concurrent users. Enhancements to the simulation tool that could aid with the future training of control engineers for Black Start restoration from distributed energy resources (DERs) include:

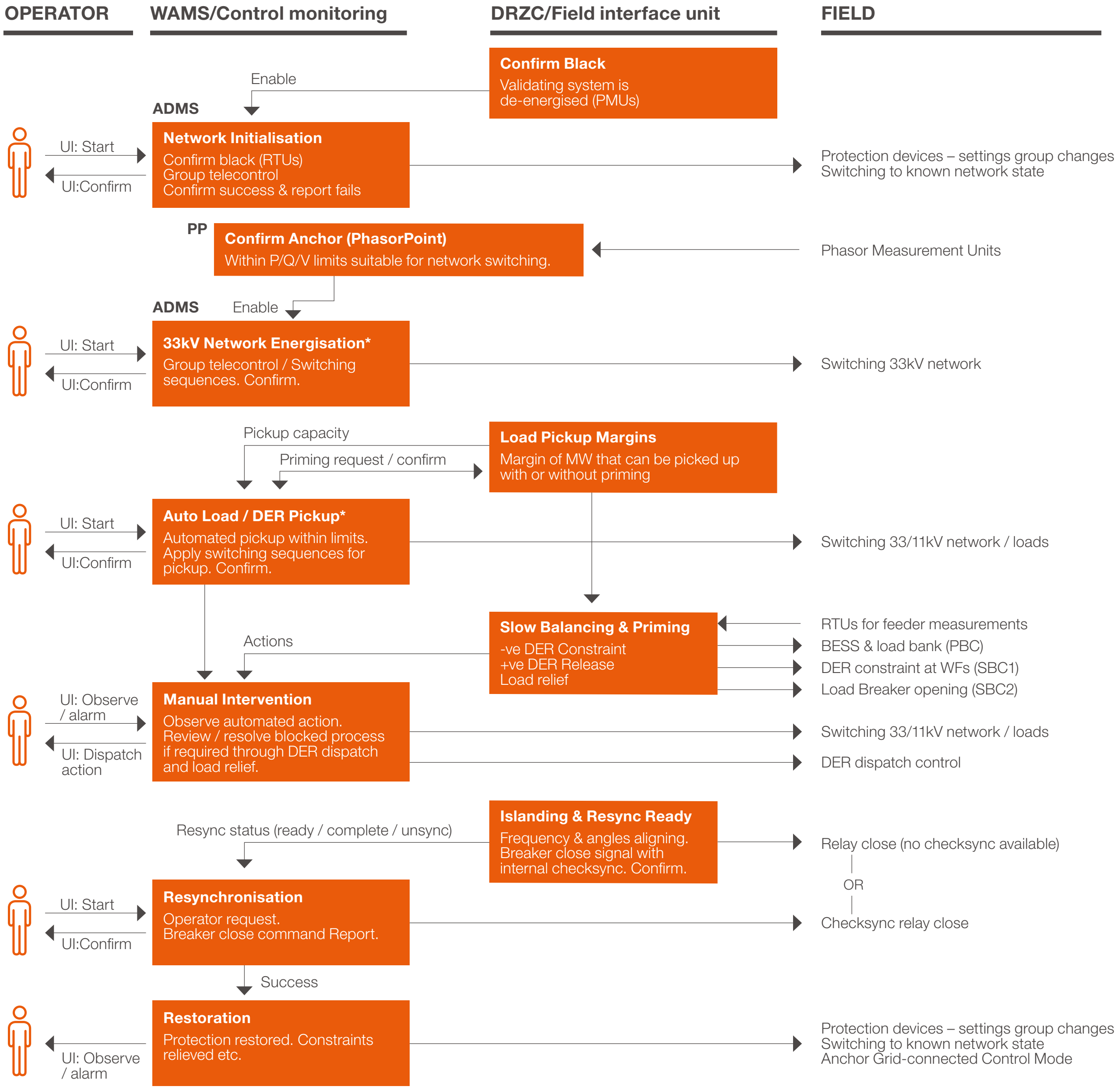
- adding additional network case studies and/or additional restoration scenarios
- connecting the back-end of the simulation tool to power simulation software to enable switching actions that are not part of a pre-defined restoration plan
- adding contingencies to the restoration such as varying wind speed, low state of battery state of charge or loss of measurements
- incorporating failure scenarios into the restoration to test disaster recovery methods across organisations
- incorporating frequency management responsibilities for the distribution network operator (DNO)
- provision for automation of restoration functions, such as would be provided by the distribution restoration zone controller (DRZ-C)
- a package simulation tool as a desktop application (instead of browser based) as this would shift most of the processing requirements to the device reducing input response lag
- incorporation of web-hooks (push notifications) to improve simulation performance and increase user capacity.

A benefit of enhancing this online simulation method for cross-industry training rather than incorporating DRZ scenarios into existing training methods is the capability to train service providers as part of the exercise, providing understanding of how their assets will be used. Furthermore, the interconnected advanced distribution management system (ADMS)/ Energy Management System (EMS) can be visually modelled without needing linking of their simulator environments.

4.3 Alignment with DRZ-C development

A key and ongoing development across the project has been the design and build of a distribution restoration zone control system (DRZ-C). This mitigates against the technical challenges associated with operating a low fault level, low inertia system, alongside the organisational impacts of delivering this procedure. The functional specification for this DRZ-C is published **(nationalgrideso.com/document/182481/download)** in the Power Engineering aspects design report 2 and has undergone continued development with intent to deliver hardware in the loop testing of a final design. Across this design and build process, it has been important to align the DRZ-C design and organisational requirements into a single procedure which makes use of the functionality that has been developed and considers human interaction and visibility requirements.

The DRZ-C design makes use of functional blocks which can be called upon across the restoration event to automate elements of the procedure, while retaining control engineer approval for transition between phases. This system will be built on the DNO network and make use of group telecontrol on the ADMS and direct measurement and setpoint control at contracted DER sites in order to maintain voltage and frequency standards to prevent inadvertent protection operation and protect the anchor DER. These function blocks are illustrated in Figure 18.



* Operator will initiate a sequence and check for success. Sequence may include one or more staggered events to minimise disturbance, checked at each stage to ensure that the action can be taken within performance limits. The ADMS will automatically choose if priming is needed for a load pickup and instruct PhC_DRZC if required. If a sequence cannot be completed, ADMS will report as a warning and proceed to the next stage until full procedure is complete. Operators then have opportunity to resolve issues manually.

Figure 18: Function blocks for the distribution restoration zone controller (DRZ-C) design

Across Chapter 6, discussion of how and why a control engineer would use these function blocks is given. However, a brief overview of each function's capability is provided in Table 3.

Table 3: DRZ-C functions

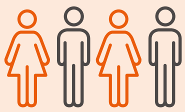
DRZ-C Function Block	Description of capability provided
Validate Zone Black	Through use of measurement points across the restoration zone, ensure all voltages have zero magnitude and flag to the control engineer any non-zero magnitude voltages for further investigation.
Initialise network	Automatic declaration to service providers of a restoration event, preparation of the switching schedule, group telecontrol of the network against the approved switching schedule and change of protection settings to (pre-determined) Black Start settings. Must be complete before anchor distributed energy resource (DER) can be started.
Anchor DER monitoring	Check for anchor operation within normal range for fast and slow balancing (including state of charge). Check for voltage and frequency near nominal levels with no oscillations. Check for proportional voltage and frequency control enabled (by distributed energy resource (DER) system) and flag to the operator an 'Anchor ready' signal.
Fast balancing	Maintains frequency and Rate of Change of Frequency (RoCoF) within defined limits by using the balancing resources available for this service; once enabled, continues to run until stopped on an operator command or emergency condition detected.
Slow balancing	Slow balancing acts on all contracted energy resources to maintain upwards and downwards margin on the fast balancing service providers. This continues to operate until an operator manual stop command or emergency condition detected.
Auto load/DER pickup (Switching sequence with priming)	Following the switching schedule (from initialise network phase), group telecontrol actions taken to the point of demand, DER or transformer connection. Look up predetermined pickup (MW/MVAr) requirements for this action, check within resource capability range. If not, use slow balancing to re-position resources and confirm capability. If still not capable, flag to operator and move to next switching sequence step. Automated sequence to complete ahead of operator switching of any flagged sites but can be aborted at any stage by the operator.
Resynchronisation	The resynchronisation function raises and lowers the frequency and distribution restoration zone (DRZ) droop characteristic to achieve frequency and voltage matching with the external source. Due to imperfect alignment of frequency, phase angles will eventually come into alignment, and the armed synchro check relay can close. An alternative method without use of a synchro check relay will be trialled through Hardware in Loop (HiL) testing using automated closure of a normal CB after alignment is measured by the distribution restoration zone controller (DRZ-C) on both sides; this would save investment costs for synchronisation options at the point of transmission connection.
Restore network	Initiates a series of teleoperations to revert protection settings, restore normal operating topology and change the DER modes of operation back to normal operational method.

5 Restoration Procedure

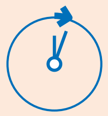
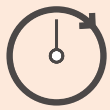
This chapter presents the proposed restoration procedure end to end, detailing the automation systems used, the likely numbers of people involved and the organisations responsible. Where appropriate, the communications method is also described.

Each action is characterised by key properties provided as an infographic alongside the high-level description of the actions taken. More detailed analysis of these actions is provided in Chapter 6, but this serves a generic methodology for the delivery of a distribution led restoration process.

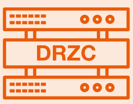
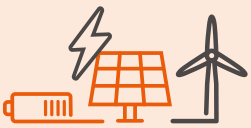
The number of staff required to deliver the action are considered. This process map attempts to characterise this as the requirement per distribution restoration zone (DRZ), but there are some stages that are common with conventional restoration and require all resources available to support. Chapter 6 reviews how this may impact on current organisational structures and staff requirements. Indicative distributed energy resource (DER) operator numbers are excluded from this infographic due to the multitude of different DER service providers and the technologies and control structures required.

	1 control engineer can manage this process alongside other activities.
	1 control engineer can manage this process but is unlikely to be able to concurrently manage other processes.
	Multiple control engineers may be needed to manage this process and are unlikely to be able to concurrently manage other processes.
	All available control engineers should support this process.

The duration for each action is estimated based on desktop exercise feedback, consultations across all GB distribution network operators (DNOs) and the preliminary findings of the ongoing distribution restoration zone controller (DRZ-C) development. These are indicative timelines only, and the spread of times when applied to a specific case study are considered in more detail in section 6.11: Assessment of time to system restoration.

	This action requires a short duration, likely under 1 minute.
	This action requires processing of data or decision making but is likely to be delivered in less than 10 minutes.
	This process requires decision making or manually instigated control actions and is expected to be delivered within 30 minutes.
	This process requires significant manual instigated changes to networks, generators or preparatory work but should be delivered within 1 hour.
	This process requires significant manual instigated changes to networks, generators or preparatory work and under many scenarios may take over 1 hour to deliver.

Categorisation of the type of automation is used across this process design providing suggested systems for delivery. Actions are considered to be either manual, enacted through grouped telecontrol on the advanced distribution management system (ADMS), directly through the newly introduced distribution restoration zone controller (DRZ-C) system or through distributed energy resource (DER) response (which may be manual or automatic).

	Actions that require manual assessment or individual actions to be taken on the ADMS/ Energy Management System (EMS) are categorised as 'manual'.
	Actions that can be carried out either completely automatically or through triggering of group telecontrol actions on the ADMS are categorised as being automated through the ADMS.
	Actions that require bespoke hardware or software functions that are defined within the DRZ-C design specification are categorised as being automated through the DRZ-C.
	Actions that depend on DER output or response to control signals (whether instigated manually or automatically) are classified as DER actions. The specific method this is delivered through will be up to the service provider and may depend both on the technology types and the top-up/anchor services they are providing.

Across the refine stage, specific focus has been given to actions that may require specific attention in training. These have been considered both as training that may be included within existing processes or those that might require dedicated training procedures to provide sufficient operational knowledge to execute the action. This is discussed in more detail in Chapter 6. Specific DER training is excluded from this review because individual DERs will have very varied training requirements dependent on their technology type and degree of automatic response.

	This does not directly lead to a new training requirement but should be considered within existing training as a potential case study.
	This process stage needs to be captured within existing training exercises but does not directly lead to new or additional formats.
	This process would need to be captured within additional DRZ specific training, either internally or as part of cross industry exercises.
	This process is an entirely new operational capability. Training alone may not be enough to provide desirable levels of competence.

This process design gives consideration to the interactions between different businesses. Voice communications reflects the current nature of most restoration-based communications, and this is maintained between network operators. The functional specification introduces the concept of fast data and slow data in line with fast balancing and slow balancing/ Supervisory Control and Data Acquisition (SCADA) communications requirements. In particular, the latency of the communications used will impact on which services or actions it can be applied to.

	Communications expected to be conducted via voice communications are characterised as 'Voice'. This may involve data exchange between systems to support situational awareness, but any instructions or information will be verbally exchanged between the businesses involved.
	Slow data requirements come about as a result of actions that do not require extremely low latency. The existing network meets this specification where the intended network independent power resilient standard is met.
	Fast data requirements come about as a result of actions that do require low latency response, largely from distribution restoration zone controller (DRZ-C) balancing actions. This network must meet the functional specification set out in the OST design II report **(nationalgrideso.com/document/182841/download)**

VISIO process map

Strategy | Electrical action | Information | Interaction

6 Process Analysis

6.1 Introduction

It is clear that the new organisational design and process requirements introduce changes across multiple businesses compared with their current restoration operational procedures. While the process map presented in Chapter 5 only covers the actions specifically related to a distribution-led restoration event, consideration is given to how this will interact with the existing requirements and how this leads to change. Across this chapter, the procedure is assessed, considering in more detail what each organisation will need to deliver, the information and data they will need to exchange, the communication and control methods they will use and any specific use of the distribution restoration zone controller (DRZ-C) functionality set out in Table 3.

The interfaces between organisations are considered, highlighting the requirements for communication to deliver against this specific stage and how this may change from the existing procedure.

The systems that are required to deliver this process stage are also given consideration. This illustrates where existing systems require change or where new systems are required.

The telecommunications requirements are provided, illustrating where new or upgraded network requirements are introduced to facilitate the systems or interface requirements.

Consideration is given to training and specific outputs from desktop exercises and consultation that has demonstrated a gap in the skills, capabilities or awareness of control engineers in respective organisations.

Finally, any requirements for different staff arrangements are discussed. Each organisation is responsible for its own resourcing plan to deliver against their responsibilities, but this represents the likely organisational burden of delivering this process stage.

Where there is a difference in the overall process between the England and Wales region and the Scotland region, this is also captured. The impact is mostly localised to Scottish transmission network owners (TOs), who assume regional responsibility for restoration under current code structures. The project does not propose to change these existing arrangements as they increase overall bandwidth for concurrent management of restoration plans.

Against these categories, a high-level scoring methodology complements the discussion. This attempts to identify the scale of change experienced by an organisation and the possible focus areas for these businesses across roll-out. This analysis is split by organisation to enable focus on the specific business area in which you are interested.

Table 4: High-level degree of change

Level of change	Score
No change is required; existing arrangements are capable of delivering this phase.	Blue
A change is required, but this will not result in significant investment costs.	Green
A change is required, but this can be resolved through investment.	Amber
A change is required but this results in enhanced process risk.	Red

6.2 Black Start Declaration

There are many possible extremely low-probability, high-impact events which may result in a Black-out. This may cause widespread national power outages or regional impacts based upon the cause, and it may not be initially clear that a Black Start scenario exists. A series of alarms will identify undervoltage in area(s) of the transmission system alongside widespread operation of protection systems. As public telecommunications are not power resilient, pre-defined, power and physically resilient communications paths between network operators are essential to declaration, ensuring all key entities are situationally aware and are able to begin re-organisation to support restoration.

6.2.1 Electricity System Operator

Through assessment of protection operation, undervoltage alarms, identification of areas disconnected from supply and potential discussion with other network operators, the decision may be taken by the Power Systems Manager of National Grid Electricity System Operator (NGESO) to declare Black Start. Grid Code Operating Code 9 gives NGESO Power System Manager the authority to declare Black Start as part of the recovery process following a total or partial shutdown. In the event of a partial shutdown, this declaration includes assessment of whether the disturbance meets the market suspension threshold or if the total system can be restored to normal operations without market suspension.

After declaration of a Black Start by the Power Systems Manager, the time is noted and transmission owners and distribution network operators (DNOs) are informed initially, followed by transmission restoration service providers. This declaration phase will initiate re-organisation in all organisations inclusive of NGESO.

NGESO will adopt a new command and control structure to manage power islands effectively and, due to the high-stress, high-workload nature of the situation, will attempt to contact relief staff and implement a shorter shift cycle. A Silver command function will be established to act as the external liaison between non-operational parties.

Table 5: NGESO change assessment for the declaration phase

Area impacted	Changes required
Interfaces	All licence area TOs and DNOs interface with NGESO in this phase. Silver command will liaise with non-operational stakeholders but is kept separate from the operational team. No changes are introduced through the project.
Systems	The principal system used in this phase is the integrated energy management system (IEMS) to support identification of a restoration event. Black Start will also be declared on the balancing mechanism reporting system (BMRS). However, if the market is suspended, then all market platforms will also be suspended.
Telecommunications requirements	The National Grid Operational network (OpTel) will be essential for all operational communications. This will carry both Supervisory Control and Data Acquisition (SCADA) data and voice traffic. No changes are introduced through the project.
Training requirements	Existing training frequency and format is suitable to meet the requirements introduced in this phase of restoration but must adjust to make clear that the DNO should be instructed to declare this to all distribution restoration service providers.
Staff requirements	This will require the focus of the full shift team, but this does not represent a change from the existing restoration requirements.

6.2.2 Transmission Owners

The transmission owners will have identified the existence of a major network disturbance within their licence area. The process of clearing alarms, identifying network status and any SCADA faults that may have resulted from loss of supplies will start ahead of declaration from NGESO. Site-based engineers and technicians will, where possible, be called to affected substations.

Upon declaration of Black Start by NGESO, this should be formally acknowledged, and the time noted. All information already gathered should be shared as this may impact on the strategy. However, until all alarms are cleared, and the network is switched to facilitate restoration plans, there will be uncertainty on availability of restoration options.

Through emergency communication systems and self-starting policies, required site engineers should be brought to strategic substations identified in restoration procedures, while control room staff continue to clear alarms and identify the true network availability.

Table 6: TO change assessment for the declaration phase

Area impacted	Changes required
Interfaces	TOs interface with the NGESO at this phase. Existing voice communication is used. No changes are introduced by the project.
Systems	The transmission management system for each licence area will be the key system used across this declaration phase. No changes are introduced through the project.
Telecommunications requirements	The National Grid Operational network (OpTel) for NGET (E&W) and the Scottish TO's operational network will be essential for all operational communications. This will carry both SCADA data and voice over IP. No changes are introduced through the project.
Training requirements	Existing training frequency and format is suitable. The only change required resulting from the project is inclusion of new key substations which facilitate distribution level restoration.
Staff requirements	There will be a reliance placed on additional resourcing being delivered as a result of called-in resource and self-starting policies. It is not anticipated that there will be any directly attributable headcount requirements resulting from a distribution restoration option. However, more strategic substations may be needed to meet the requirements introduced as a result of the Electricity System Restoration Standard.
Regional differences	In Scotland, the transmission owner (TO), on agreement or loss of communications with National Grid Electricity System Operator (NGESO), may assume responsibility for enacting procedures within its licence area. This will include newly introduced distribution restoration zone plans (DRZPs) and existing local joint restoration plans (LJRPs).

6.2.3 Distribution Network Operators (DNOs)

The DNO will have identified the existence of a major network disturbance within its licence area. The process of clearing alarms, identifying network status and any Supervisory Control and Data Acquisition (SCADA) faults that may have resulted from loss of supplies will start ahead of declaration from NGESO. Site-based engineers and technicians will, where possible, be called to affected substations.

The distribution restoration zone controller (DRZ-C) introduced through the project will support this process of identifying network state within the restoration zone. This will involve running a Validate Zone Black process within the DRZ-C which will validate that any voltage measured within the restoration zone is zero magnitude. Any non-zero magnitude will be flagged to the DNO control engineer via the advanced distribution management system (ADMS) for further review.

Declaration of Black Start by NGESO should be formally acknowledged, and the time noted. All information already gathered should be shared as this may impact on the strategy.

After acknowledging NGESO's Black Start declaration, the Initialise Network function should be run within the DRZ-C. This will run a pre-programmed group telecontrol sequence through the ADMS to change protection settings to island mode and identify current circuit breaker status and availability of the contracted (anchor and top-up) service providers within the DRZ. It will also provide a notification to providers of a restoration event to enable readiness procedures to be implemented through the distributed energy resource (DER) control systems.

Table 7: DNO change assessment for the declaration phase

Area impacted	Changes required
Interfaces	The DNO interfaces with NGESO and DER via the DRZ-C. This is a change introduced as a result of the project. The use of automation to both issue declaration of Black Start and receive an initial availability signal would not be considered as a significant change.
Systems	There is a requirement for a new control system to be introduced which mitigates against a higher resource requirement. This DRZ-C will interface via a user interface introduced on the ADMS specifically for restoration. In addition, there is a requirement for additional batch sequence scripts on the ADMS to validate the circuit breaker status and change protection settings groups.
Telecommunications requirements	An extension to the existing power resilient DNO communications network is required to the DER site. This will only apply to contracted providers to minimise the cost requirements. An upgrade to the resilience of the central communications network for DNOs are required to be completed.
Training requirements	Training on the DRZ-C will be essential within DNOs at least biennially for familiarity. As all DNOs may not use the same DRZ-C system integrator, there will need to be additional whole-industry training currently run by NGESO.
Staff requirements	Through introduction of automation, impacts on direct DNO resourcing will be limited. However, if restoration occurs at times of minimum resourcing, self-starting policies will be necessary to manage this alongside conventional restoration procedures for which the distribution network operator (DNO) is still responsible in facilitating block loading. It is anticipated that one control engineer will be required on average to supervise, monitor and trigger actions within a single distribution restoration zone controller (DRZ-C).
Regional differences	In Scotland, it is possible that the DRZ-C may span transmission and distribution voltages due to a possible requirement for fault infeed source at 132kV for energisation of 400kV. This would require a specific contract covering control of these assets by the DNO and likely require verbal approval by a transmission authorised control engineer.

6.2.4 Distribution Restoration Service Provider

All DER will first experience loss of mains supply resulting from the loss of mains event and will have disconnected from the grid on detection. All contracted service providers will be required to demonstrate a controlled shutdown capability in response to this, maintaining essential supplies to communications and essential auxiliaries.

On receipt of an Initialise Network signal from the DNO, the energy resource will be required to provide an availability signal showing controlled shutdown and any deviation from its pre-agreed capability under the DRZ plan.

Table 8: DER change assessment for the declaration phase

Area impacted	Changes required
Interfaces	The DER will have interface with the DNO via the DRZ-C and via a voice communications option intended only for back-up use in the event of automation failure or emergency situation.
Systems	The DRZ-C will minimise the numbers of systems changes required within energy resource providers by issuing instructions that match operational modes available to achieve alternate control methodologies needed for restoration. Therefore, the key requirement will be an appropriate interface with the DNO owned DRZ-C system. However, the resource must be upgraded to meet the Distributed ReStart functional specification for the service it provides.
Telecommunications requirements	There will be a DNO provided power resilient communications link to the point of resource connection. However, it is the responsibility of the energy resource to provide the required extension of power resilient communications to the point of use. Where supervisory control is required from a remote location, this will be the responsibility of the provider and if essential for service provision will be included within the assurance scope.
Training requirements	Where a DER is a manned site, new training will be needed in order to respond to a restoration signal.
Staff requirements	This may include the addition of protocols or procedure to bring staff to site or an increase to the overnight staffing levels to maintain a minimum capability. Where a DER is remotely controlled, it is expected that instruction from the DRZ-C will mitigate the need for new training or additional staff requirements.

6.3 Information Gathering

After all parties have become aware of a restoration event, situational awareness will be the key issue for all network operators. It is essential that knowledge of the availability of all energy resources and network routes factor into the sequencing of restoration start-up. The overall aim of this stage is to collate all this information within National Grid Electricity System Operator (NGESO) to allow for national prioritisation and meet the regional requirements set out in the Electricity System Restoration Standard.

6.3.1 Electricity System Operator (ESO)

NGESO will focus on establishing transmission network availability alongside restoration service providers and distribution restoration zones. A key consideration is the state of fuel/charge/power available of the provider(s) as the duration for which a plan can operate independently is critical for ensuring power islands can be synchronised to further grow the skeleton network. It will need knowledge of both transmission level and distribution level plan availability and awareness of additional resources that can be used in the local area. This strategy should enable restoration of 60 per cent demand within a 24-hour period, and for this reason, instruction to start a distribution level plan should only be withheld where it has a time limited output of under 5 days (requirement for 100 per cent network energisation) or where it requires transmission system access. Under these circumstances, it is important to consider the start sequence with reference to the wider restoration procedure.

Table 9: NGESO change assessment for the information-gathering phase

Area impacted	Changes required
Interfaces	Supervisory Control and Data Acquisition (SCADA) interfaces are required between National Grid Electricity System Operator's (NGESO's) integrated energy management system (IEMS) and transmission network owner's (TO's) IEMS, distribution network operator's (DNO's) DMS and distribution restoration zone controller (DRZ-C) residing on the DNO's network. The information displayed on NGESO's network will only be used to provide situational awareness to NGESO, and no command instructions will be issued from NGESO. The Inter-Control Centre Communication Protocol (ICCP) is currently planned to provide this interface between the systems. Control telephone for voice communication is also available at this stage for queries and clarifications between control rooms. The ICCP link will be a new requirement for some DNO connections.
Systems	The systems involved are the IEMS and outputs from the interconnected DMS/ DRZ-C. The DRZ-C is a new requirement.
Telecommunications requirements	The existing National Grid Operational network (OpTel) and the fibre connection to the DNO's will be in use. National Grid Electricity Transmission (NGET) (E&W TO) currently share the same OpTel network with NGESO. In Scotland, the existing network (mostly fibre) connections to the TO's will be used.
Training requirements	There will be a requirement for the existing training for electricity restoration to include consideration of DRZ, with a focus on how prioritisation decisions should be made where there are competing plans in an area.
Staff requirements	NGESO will not experience any differences in staff requirements as a result of DRZ options being available. Each DRZ will require less NGESO work during information gathering due to automatic data collection by the DRZ-C and the DNO to provide availability of plans.
Regional differences	In Scotland, the TO is able to manage its own regional strategy, as this results in more concurrent restorations, and this also applies to distribution level restoration options.

6.3.2 Transmission Owners

It is recognised that after loss of supplies, there will be uncertainty on the availability of all critical assets due to possible network and telemetry failures. For this reason, information gathering is an iterative process alongside network preparation and clearing alarms. The objective of this stage is to identify the ability of the transmission network to support skeleton network growth between contracted restoration providers and to deliver the demand source in the case of local joint restoration plans (LJRPs). When confident in the network's state, this information should be passed to NGESO for assessment within the national strategy. For Scotland, while this information should be relayed, TOs will work with the DNO to instruct the start of DRZ or LJRP directly.

Table 10: TO change assessment for the information-gathering phase

Area impacted	Changes required
Interfaces	The TOs will be using SCADA interface to gather information about the network state. They will also use the control telephone for voice communication to NGESO and DNO where required.
Systems	The IEMS or transmission management system is the main system in use by TOs to gather network information.
Telecommunications requirements	The National Grid Operational network (OpTel) used by NGET and Scottish TO's operational networks are in use for information gathering. The availability of the networks during Black Start is fundamental. There are other key functional requirements that the networks need to meet. These requirements are mostly in line with existing operational requirements. 72hrs independent power resilience across the Black Start fleet may be a new notable one that may need a network upgrade.
Training requirements	There are no new skills or processes introduced for transmission network owners (TOs) across this stage, so additional training will be limited to developing an understanding of the new network areas affected. This does result in a training requirement, but it is not different to conventional restoration.
Staff requirements	There are no staff impacts experienced by the TO directly resulting from a distributed procedure.
Regional differences	In Scotland, the TO is able to manage its own regional strategy. Information should be shared with National Grid Electricity System Operator (NGESO) to support national strategy, but plans can be implemented independently.

6.3.3 Distribution Network Operators (DNOs)

The initialise network function in the distribution restoration zone controller (DRZ-C) will identify the availability of the restoration zone used for provision of the distribution level service, should anchor providers fail to respond automatically. The DNO may be able to contact site staff through voice over IP introduced alongside the automatic interface. The initialise network function should trigger data sharing from the provider showing any deviation from pre-defined service characteristics including time to connect, state of fuel/charge/last power available to enable the DNO to make an informed decision on overall plan availability.

When confident in the wider network state and the information returned from the initialise network function, this information should be passed to NGESO for assessment within the national strategy.

Table 11: DNO change assessment for the information-gathering phase

Area impacted	Changes required
Interfaces	The DNOs will be using the Supervisory Control and Data Acquisition (SCADA) interface to gather information about the network state. The DRZ-C will require network interface with distributed energy resources (DERs), and is a new requirement introduced by the project.
Systems	The systems used for information gathering are the distribution management system (DMS), DRZ-C and voice communication system.
Telecommunications requirements	The DNO will require a resilient telecommunications network from the DRZ-C to the DERs. The DRZ-C will gather information on the state of the DERs. This could be provided either by a new network or the upgrading of an existing network in line with the functional specification.
Training requirements	DNO staff will need training on the specific implementation of the DRZ-C used by each DNO. This will require at least biennial training which must be individual to the DNO and their systems. This should be in addition to existing joint exercises between the TO, DNO and NGESO.
Staff requirements	Automation should relieve the resourcing pressure on DNOs, but there will either be a reliance on called-in resources, self-starting policies or non-concurrent plan management to prevent a change to minimum staff requirements. This additional resource requirement is not present across the information-gathering stage due to DRZ-C initialise network functionality enabling the use of called-in resources or self-starting policies.
Regional differences	In Scotland the information gathered may be passed to the TO directly.

6.3.4 Distribution Restoration Service Provider

On receipt of the initialise network function from the DRZ-C, this should trigger any required preparatory actions to validate the energy resource's capability to provide the contracted service. Dependent upon the resource type, site staff may be required to facilitate these processes. This will require a minimum staffing level capable of implementing these procedures, use of called-in dedicated support engineers with self-starting policies or an automated start sequence on DRZ-C trigger. Information should be shared with the DNO indicating any deviation in the resources' ability to deliver the restoration service compared with the restoration plan. Data to be shared include time to connect, state of fuel, state of charge or last power available alongside any service-specific parameters. This data sharing must be possible under minimum staff levels at the site. The service delivery could subsequently be carried out with called-in resources. Service providers should implement the service start sequence to the point at which fuel/charge would be used.

Table 12: DER change assessment for the information-gathering phase

Area impacted	Changes required
Interfaces	A new resilient interface between the distributed energy resources (DERs) and the distribution restoration zone controller (DRZ-C) is required.
Systems	The DERs will depend on their energy management system and Supervisory Control and Data Acquisition (SCADA) network to get the necessary information for the initial information-gathering stage. The DRZ-C is intended to gather generator dynamic information automatically.
Telecommunications requirements	A new telecommunications network service between the DERs and DRZ-C is required. A voice communication network service is also required for backup purposes, and these should be in line with the functional specifications.
Training requirements	Where a site requires control engineers to initiate a restoration, the staff should be trained at least biennially on the information-gathering procedure.
Staff requirements	It is essential that information gathering and sharing can be done using minimum staffing conditions. While the overall restoration process can be delayed to account for called-in resources, this process must either be automated or possible to conduct with the lowest resourcing level for the site.

6.4 Instruction of the Distribution Restoration Zone

After it has been confirmed that the distribution restoration zone (DRZ) is viable for use within national strategy or Scottish regional strategy, National Grid Electricity System Operator (NGESO) or Scottish transmission network owner (TO) will instruct the start to network operators, who will confirm their readiness to proceed and begin implementation of the distribution restoration.

6.4.1 Electricity System Operator

After information gathering, NGESO will define the national strategy through assessment of the effectiveness of DRZ options and local joint restoration plans (LJRPs). NGESO should instruct the start of these procedures. It should consider distribution network operator (DNO), TO and NGESO resource requirement for concurrent restoration plans within licence areas alongside skeleton network path, demand that can be restored, time to connection and time that the energy resource(s) can independently sustain supply output. When confident in the strategy, it should consult DNO and TO control engineers on ability to facilitate the restoration zone and, on confirmation of readiness, then instruct the start of the DRZ including the identified transmission network route where applicable.

Table 13: NGESO change assessment for the DRZ instruction phase

Area impacted	Changes required
Interfaces	The instruction of the DRZ-C will use the interface between the integrated energy management system (IEMS) and the DRZ-C Inter-Control Centre Communication Protocol (ICCP) and the control telephone interface. The function will be to inform the DNOs, who will trigger the start of the DRZ-C.
Systems	The systems used in this process are the IEMS, DRZ-C and control telephones.
Telecommunications requirements	The National Grid Operational network (OpTel) used by NGESO and the DNO operational networks are used for the instruction of the DRZ-C. This is configured for data and voice traffic.
Training requirements	NGESO will need training on evaluation of distributed procedures in tandem with conventional LJRP . The decision on when to instruct the start of plans should make consideration of resourcing levels across DNOs, alongside technical parameters of time to connect, state of fuel/ state of charge and power available for the DRZ. It is recommended that each DNO is limited to only managing one DRZ at a time during the initial roll-out, so NGESO should prioritise the procedure with most impact in that region.
Staff requirements	There is no impact on the staff requirements across the instruction phase of restoration.
Regional differences	In Scotland, the transmission network owner (TO) can take on the role of instruction and plan prioritisation to increase the number of plans that can be run in parallel. This does not represent a change from existing regional arrangements.

6.4.2 Transmission Owners

The TO will continue switching the transmission network to make ready skeleton transmission restoration options and local joint restoration plans (LJRPs) and distribution restoration zone (DRZ) network paths. On request from National Grid Electricity System Operator (NGESO) of readiness, TOs will assess its capability to implement the specific restoration option including availability of network and capability of staff to manage any concurrent restorations. TO control engineers must ensure isolation from the instructed DRZ.

The Scottish TO may take on NGESO function within its licence area during this phase.

Table 14: TO change assessment for the DRZ instruction phase

Area impacted	Changes required
Interfaces	The TOs will use the Supervisory Control and Data Acquisition (SCADA) interface to switch their network in readiness for instruction of the distribution restoration zone controller (DRZ-C).
Systems	The integrated energy management system (IEMS) is the primary system in use. The control telephone will be used to communicate during this period if required.
Telecommunications requirements	The existing National Grid Operational network (OpTel) (E&W TO) and the operational network of the TO's (Scottish TO) will be in use.
Training requirements	There are no new requirements introduced on the TO across this stage. Network preparation should be instigated by the instruction of a DRZ similarly to a LJRP.
Staff requirements	There are no direct resource increases resulting from a DRZ across this phase.
Regional differences	In Scotland, the TO can take on the role of instruction and plan prioritisation to increase the number of plans that can be run in parallel. This does not represent a change from existing regional arrangements.

6.4.3 Distribution Network Operators (DNOs)

The DNO will continue switching the distribution network to make ready DRZs and blocks of demand for LJRP. On request from NGESO of readiness, it will assess its capability to implement the specific restoration option including availability of network and capability of staff to manage any concurrent restorations. After agreement and instruction from NGESO, the DNO will use the advanced distribution management system (ADMS) to instruct the start of the anchor distributed energy resource (DER). DNO control engineers must ensure isolation of the instructed DRZ from the transmission network inclusive of any distribution level interconnection.

Table 15: DNO change assessment for the DRZ instruction phase

Area impacted	Changes required
Interfaces	The SCADA interface to the DNO networks will also be used to switch their network in readiness for the instruction of the DRZ-C. However, a new interface from the DRZ-C to the DERs will be required for the DRZ-C instruction.
Systems	The systems required in this phase are the DNO's distribution management system, the DRZ-C system and any interface systems on the DER end.
Telecommunications requirements	The DNO network is primarily used. The project has introduced a new requirement of extending the DNO network to the DERs so the DRZ-C can communicate with the DERs. This extended network is existing in some cases; however, it should satisfy the proposed functional specification.
Training requirements	It is a new requirement for the DNO to emergency instruct the DER . As a result, specific training on generator despatch will be required. As instruction will be through the DRZ-C, it should be included within the training programme for the specific implementation used by the DNO.
Staff requirements	Distribution network operator (DNOs) will require greater than minimum resourcing to deliver distribution restoration zone (DRZ) in parallel with local joint restoration plan (LJRP). However, called-in resources and self-starting policies supported with the distribution restoration zone controller (DRZ-C) for initial information-gathering stages will enable this to be met without recruitment of additional staff.

6.4.4 Distribution Restoration Service Provider

All service providers should continue to follow their startup procedures until the point at which fuel (or charge) is required. On receipt of an instruction to start from the DNO, the anchor distributed energy resource (DER) should acknowledge and share a time to connect estimate with the DNO.

Table 16: DER change assessment for the DRZ instruction phase

Area impacted	Changes required
Interfaces	A new or upgraded network interface is required from the DER to the DRZ-C.
Systems	The DERs will rely on their existing system, and there is no new requirement except where remote control system for the DER doesn't exist or the system requires upgrading in order to connect with the DRZ-C.
Telecommunications requirements	The DER will require the network extended to the DRZ-C. This could either be by upgrading the existing network to the functional specification or a new network, whichever is more feasible or economical.
Training requirements	As highlighted through desktop exercises, training requirements for the DER should include joint exercises with DNOs so they are familiar with the specific operating capabilities of the generation type.
Staff requirements	Restoration service providers are required to deliver their service within eight hours from instruction. Where this requires staff called in, this should be included within the time to delivery.

6.5 Pre-energisation

After the anchor DER has been instructed to start, it will follow the start procedure to the hold point at which within 20 minutes from instruction by the DNO it will be able to deliver the contracted capability.

6.5.1 Electricity System Operator

National Grid Electricity System Operator (NGESO) has no role within pre-energisation; while an Inter-Control Centre Communication Protocol (ICCP) link will provide situational awareness of DRZ progression, no changes will be visible across this stage.

Table 17: NGESO change assessment for the pre-energisation phase

Area impacted	Changes required
Interfaces	The ICCP link will provide situational awareness to the NGESO team.
Systems	The systems used here is the integrated energy management system (IEMS), which provides situational awareness to NGESO control engineers.
Telecommunications requirements	There is no new requirement from NGESO end for this stage. The National Grid Operational network (OpTel) and the DNO operational network will be used to provide situational awareness to NGESO control engineers.
Training requirements	There is no requirement for NGESO training.
Staff requirements	There is no requirement for NGESO staff during this stage.

6.5.2 Transmission Owners (TOs)

The transmission owner will, in line with the instructed restoration route from NGESO, continue switching the network off-load to minimise the number of switching actions required after energisation and reduce the consequential trip risk. This will be a pre-defined set of switching actions corresponding to individual LJRPs/distribution restoration zone plans (DRZPs).

Table 18: TO change assessment for the pre-energisation phase

Area impacted	Changes required
Interfaces	This will use the existing Supervisory Control and Data Acquisition (SCADA) interface to various switching points in the transmission network owner (TO) network. This enables TOs to switch necessary networks, and there are no new requirements for this stage.
Systems	The TO's energy management system will be in use.
Telecommunications requirements	The National Grid Operational network (OpTel) (E&W) and TO's operational network will be used, and there are no further requirements.
Training requirements	There is no change introduced through this procedure being that this is from the distribution network. However, specific training on the switching sequences required as part of a new restoration option will be required as part of developing the switching programme.
Staff requirements	There is no impact through this procedure being distributed.
Regional differences	The Scottish TO can independently decide on the restoration route most suitable for its available procedures whereas in England and Wales, National Grid Electricity System Operator (NGESO) should be consulted to instruct a new option if the instructed route becomes unavailable.

6.5.3 Distribution Network Operators (DNOs)

The initialise network process triggered in the advanced distribution management system (ADMS) will put the network in an optimal pre-restoration state to minimise online switching actions. However, a DNO control engineer must validate this network state ahead of progressing to the next stage. Furthermore, the distribution restoration zone (DRZ) energisation strategy must be defined by the control engineer. This will depend upon outputs received from the distributed energy resources (DERs) (top-up and anchor) and may include considerations such as power available. After validation of the pre-energisation state of the network, development of the energisation strategy and confirmation from the anchor DER reaching hold point, the DNO control engineer should instruct through the ADMS energisation of the DNO network.

Table 19: DNO change assessment for the pre-energisation phase

Area impacted	Changes required
Interfaces	This stage will require interfaces between the DMS, distribution restoration zone controller (DRZ-C) and DERs.
Systems	The distribution management systems (DMS), DRZ-C system and DER systems are in use.
Telecommunications requirements	The DNO's operational network play a crucial role. This will also include the extended network to the DERs.
Training requirements	Specific training both on the initialise network function within the DNOs specific DRZ-C implementation and how strategy is to be developed for a restoration zone option. As this will be implemented using familiar ADMS functions, there will not be a specific need for training on implementation or checking the network status.
Staff requirements	The automation introduced should mitigate against additional resource requirements across this phase. However, if operating this in parallel with the local joint restoration plan (LJRP), there may be an additional resource requirement on the DNO.
Regional differences	There are no regional differences affecting the DNO across this phase.

6.5.4 Distribution Restoration Service Provider

On instruction of the start of the DRZ plan, the anchor DER should complete its restoration procedure to the hold point within 20 minutes from instruction. This process will be individual to each technology type, and a valid operational procedure will need to be demonstrated as part of service assurance. This process is included within the period for which the anchor DER is required to provide a sustained output, and therefore fuel/stored charge can be used.

Table 20: DER change assessment for the pre-energisation phase

Area impacted	Changes required
Interfaces	The interface between the distribution restoration zone controller (DRZ-C) and distributed energy resource (DER) is required in this stage.
Systems	The systems in use are the DRZ-C, DER interface systems and distribution network operator (DNO's) distribution management system (DMS).
Telecommunications requirements	The DNO's operational network extended to the DERs to connect the DRZ-C to DER network will be in use.
Training requirements	There is a requirement for service providers to implement processes needed to deliver against their technical specification. For the anchor DER, this includes bringing the DER to the point of readiness to deliver its service through a completely contained resilient supply source. This process must be delivered so the service can be provided no later than eight hours after instruction from the DNO. Given this requirement and the variety of different supply technologies available, each DER will require a robust training procedure to bring it to the point of service delivery where staff are required to deliver this or an automatic procedure that delivers this. The DER will be required to prove this capability as part of assurance procedures.
Staff requirements	Dependent upon the technology, there may be a requirement for additional staff to deliver against this. Typically, this would require one to three minimum full-time equivalent (FTE) to deliver the procedure; this requirement is built off the requirements for normal start-up procedures.

6.6 Anchor DER Stabilisation

After the anchor DER has been instructed to start, it will be brought online using proportional regulation mode. This will be monitored by the DRZ-C for stability, but it will not take direct control. Dependent upon the technology type, it may be necessary to apply a stabilising demand. This may be through a storage provider, i.e. battery, flywheel or through a source of flexible demand such as a load bank which should also provide the fast balancing functionality for the power island.

6.6.1 Electricity System Operator

National Grid Electricity System Operator (NGESO) has no role within anchor DER stabilisation. However, it will maintain situational awareness through an Inter-Control Centre Communication Protocol (ICCP) link, providing an aggregate view of the power island capability.

Table 21: NGESO change assessment for the anchor DER stabilisation phase

Area impacted	Changes required
Interfaces	The ICCP link will provide situational awareness to NGESO control engineers during this stage.
Systems	NGESO's integrated energy management system (IEMS) system will provide situational awareness to NGESO control engineers. The DRZ-C system will be providing this to the IEMS.
Telecommunications requirements	The existing National Grid Operational network (OpTel) and DNO's operational network will be used here.
Training requirements	NGESO control engineers will need to be provided with training on monitoring of a distribution level power island through ICCP mapping to reduce the overall requirement on operational telephone communications. However, there is no direct control requirement.
Staff requirements	There are no control requirements for NGESO at this stage of the process, meaning there are no additional staff requirements.

6.6.2 Transmission Owners (TOs)

The TO has no role within anchor DER stabilisation and does not require situational awareness. It is essential that the TO is isolated from the DRZ, but this is confirmed as part of the previous stage.

Table 22: TO (transmission network owner) change assessment for the anchor distributed energy resource (DER) stabilisation phase

Area impacted	Changes required
Interfaces	There are no requirements from the TOs at this stage.
Systems	There are no requirements from the TOs at this stage.
Telecommunications requirements	There are no requirements from the TOs at this stage.
Training requirements	There is no procedural difference at this stage which requires training for the TO. A requirement to isolate from the distribution network already exists.
Staff requirements	There are no control requirements for National Grid Electricity System Operator (NGESO) at this stage of the process, meaning there are no additional staff requirements.
Regional differences	There is no difference for England and Wales or Scottish TOs.

6.6.3 Distribution Network Operators (DNOs)

After instruction to energise, the DNO will await confirmation of energisation to the point of DNO connection from the anchor DER. Any stability issues with the start procedure will be identified to the control engineer via the distribution restoration zone controller (DRZ-C). After confirmation of stable start procedure, the DNO will close the customer circuit breaker and energise to the point of stabilising demand connection (where applicable). These processes will be triggered via a command to the advanced distribution management system (ADMS). On DNO control engineer trigger, the ADMS will implement the pre-agreed sequential loading of the demand source (where applicable).

This source of stabilising demand may be an additional top-up service provider, or a generator installed capability.

The DRZ-C will continue to monitor stability of the anchor DER across this loading procedure, and when enabled by the DNO control engineer through the 'initialise balancing' function, will commence slow balancing (maintaining a consistent state of loading across generation resources including maintenance of headroom on the assets) and fast balancing (maintaining stability of the energy resources by managing the rate of change of frequency and changing setpoints on the source of stabilising load to arrest a fall/rise in frequency).

After DRZ-C balancing is enabled, the DNO control engineer will confirm stable operation of the anchor DER by the DRZ-C ahead of progressing to the next phase.

Table 23: DNO change assessment for the anchor DER stabilisation phase

Area impacted	Changes required
Interfaces	The interfaces between the DMS, DRZ-C and DER are important at this stage.
Systems	The systems in use are the DMS, DRZ-C and DER systems.
Telecommunications requirements	The DNO operational network with extension to the DERs is the key infrastructure required at this stage. This will connect the systems required. Low latency requirement for fast balancing is critical for the infrastructure. The network should therefore be in line with the functional requirements.
Training requirements	At this stage, frequency control capabilities are required within the DNO. While this is similar to the requirement for balancing through application of demand in conventional block loading, this represents a major change from normal operability requirements and includes a new capability of instruction of generation. It is not likely that this capability will develop under normal distribution system operations. However, future operability services including SSE's Resilience as a Service (RaaS) project and WPD's Network Islanding investigation may result in periods for which the DNO actively manages frequency. As Distributed ReStart will be the first process to require this capability within DNOs, although will not be called on except under an emergency condition, it is essential that training focuses on this specific capability despite the support received through automation. This has received specific challenge from the academic panel in the Engineering Advisory Council (EAC) as a point where disaster recovery procedures will be crucial and methods to augment training through direct experience would be beneficial. Desktop exercises were not able to simulate the management of frequency or the impacts of loss of load or loss of automation events, but future simulations needed for training would require this. Furthermore, where an outage can be taken without compromising customer load, control of flexible demand will enable direct assurance of the automation and exposure to frequency control capabilities.
Staff requirements	Due to the use of automation, it is expected that one distribution network operator (DNO) control engineer will be capable of managing a single distribution restoration zone (DRZ) inclusive of loading the anchor to a stable operating position. However, with familiarity and increased levels of training and confidence in automation, a DNO control engineer may manage multiple islands in parallel allowing stable operation to be maintained by the DRZ-C while focus is spent on assessing the suitability of transitional phases. This is not recommended for initial roll-out but mitigates against an exponential engineering requirement.

6.6.4 Distribution Restoration Service Provider

On instruction to energise the anchor distributed energy resource (DER) from the DNO, the start-up sequence should be initiated. This is individual to the provider but will include use of an emergency generator to provide self-starting capability through powering auxiliaries. The DER will be started in proportional regulation mode with target nominal voltage and frequency.

The anchor DER should energise to the point of DNO connection, monitoring for stable operation including monitoring of revolutions per minute (RPM) (where applicable) and voltage. The distribution restoration zone controller (DRZ-C) will provide visibility of any stability issues to the DNO control engineer, who may choose to abort the anchor start sequence, but DER systems will be used for monitoring its own stable operation.

After stable self-start is achieved, the DNO will be notified by the anchor DER of successful start-up.

Table 24: DER change assessment for the anchor DER stabilisation phase

Area impacted	Changes required
Interfaces	This stage requires interface between the DER and DRZ-C on the DNO network.
Systems	The DRZ-C, distribution management system (DMS) and DER systems are required.
Telecommunications requirements	The DNO's operational network which is extended to the DER interface is required.
Training requirements	Anchor and top-up service providers may both be included within this stage (where the flexible demand source is a top-up service provider) and must demonstrate an effective training capability through assurance visits. In particular, this phase will require a robust self-starting procedure for the anchor DER and demonstration of automatic fast control of load from the provider of flexible demand.
Staff requirements	The anchor DER is required to have sufficient engineering resource to deliver against this requirement within eight hours of instruction to the point of energisation. This also applies to any top-up service providers from the point of DRZ instruction.

6.7 Distribution Restoration Zone Growth

After successful stabilisation of the anchor DER, multiple restoration strategies exist (see section 2.4). It is expected that the immediate next steps will be to energise all top-up service providers at a 0MW setpoint, followed by either transmission network energisation or connection of demand through a block loading sequence. These capabilities are achieved through use of the DRZ-C but represent the biggest changes from the current process for DNOs.

6.7.1 Electricity System Operator

National Grid Electricity System Operator (NGESO) will maintain situational awareness through an Inter-Control Centre Communication Protocol (ICCP) link providing an aggregate view of the power island capability. NGESO should be notified of progress by the distribution network operator (DNO) where energisation occurs of a higher voltage level only (33kV to 132kV) or when the DNO is ready to use the distribution restoration zone (DRZ) in national strategy and has completed the pre-defined DRZ plan. If the transmission network is not ready to support restoration or NGESO is not ready to grow the skeleton network, the DNO should be able to maintain power island stability without transmission network energisation.

In Scotland, NGESO does not need to be notified of transmission network energisation where this occurs within the pre-defined DRZ procedure due to use of a 132kV connected top-up/anchor service provider or use of the 132kV network for interconnection between energy resources.

Table 25: NGESO change assessment for the DRZ growth phase

Area impacted	Changes required
Interfaces	The ICCP link is required to provide situational awareness to NGESO control engineers only.
Systems	NGESO's integrated energy management system (IEMS), DNO's distribution management system (DMS) and distribution restoration zone controller (DRZ-C) are key systems in use.
Telecommunications requirements	NGESO's OpTel network for situational awareness and the DNO's operational network, which has been extended to the distributed energy resources (DERs), are the key requirements.
Training requirements	DRZ growth will require training for NGESO control engineers in observation of a DRZ-C (as aggregated through the DRZ-C) to define later growth stages of restoration and remain situationally aware throughout the process.
Staff requirements	There is no operational action required for NGESO across the distribution restoration zone growth stage until completion of the pre-defined DRZ plan.

6.7.2 Transmission Owners (TOs)

National Grid Electricity Transmission (NGET) should confirm to NGESO when it is able to support wider network restoration in the DRZ network area but has no active role within restoration zone growth.

In Scotland, TOs will determine when it is suitable to use a DRZ within regional energisation strategy equivalent to NGESO's role during this phase. Should 132kV network require energisation within the pre-determined DRZ plan, the TO control engineer will be responsible for initiating this network switching action.

Table 26: TO change assessment for the DRZ growth phase

Area impacted	Changes required
Interfaces	The TOs are not actively involved at this stage.
Systems	The TOs are not actively involved at this stage.
Telecommunications requirements	The TOs are not actively involved at this stage.
Training requirements	For the England and Wales TO, there will be no specific training requirement as a result of this stage of distribution level restoration. In Scotland, this does not represent a change in existing procedures where it is responsible for regional strategy but does lead to a requirement for enhanced understanding of the capability of distribution level power islands through one-off training and incorporation into ongoing cross-DNO/TO training.
Staff requirements	There should be no impact on staff requirements for the TO.
Regional differences	In Scotland, 132kV network could be used as part of a predetermined DRZ plan. As the DNO and TO licences are presently operated by the same businesses, a transmission authorised operator may assume control of the DRZ-C (and DNO advanced distribution management system (ADMS) across this process if they also hold the relevant distribution authorisation. Interconnection of control capabilities at distribution and transmission level enables this in Scotland.

6.7.3 Distribution Network Operators (DNOs)

After stable operation of the anchor distributed energy resource (DER) is established, the DNO will follow a pre-block loading procedure to the point of demand connection or top-up service provider connection. This will be done through engineer trigger of group tele-control programmes in the advanced distribution management system (ADMS) energising pre-defined network segments (up to two automated tries before flagging for manual intervention). The distribution restoration zone controller (DRZ-C) will continue to monitor the generator for voltage stability, flagging to the DNO control engineer any issues caused through energisation of a section under no load.

It is recommended that energisation of top-up service providers is prioritised ahead of demand connection. This will improve the power island reactive range, block load pickup capability, fault infeed level and inertia. To energise a top-up service provider, the DNO must confirm readiness to deliver the service through the ADMS. On receipt of this signal, a group telecontrol action (where applicable) will be taken to energise to the point of connection. The DNO control engineer will instruct the top-up service provider to join the power island with a 0MW output. The DER will then confirm closure of its generator breaker (where applicable); the DNO will then close the customer circuit breaker to energise the site. It may take up to 20 minutes for the top-up service provider to provide voltage support, but when available, the DRZ-C can manage fast balancing and slow balancing (as enabled by the DNO control engineer). This process is iterative, and further top-up service providers may be energised before or after connection of demand customers. DRZ-C slow balancing will continually optimise the loading across generators to maximise block loading capability and headroom across generation types through issuing updated setpoints.

After completion of the pre-block loading network energisation process and in line with the wider DRZ restoration strategy, demand will be reconnected by the DNO in block loads. The size these loads must be split depends upon the combination of resources energised in the power island. In previous steps, the network has been pre-configured through group telecontrol actions to balance minimum switching actions and acceptable maximum block load sizes. The maximum size of segregated load will be calculated ahead of the restoration event, and on approval from the control engineer, the ADMS switching procedure can be implemented. Due to the cold load effect – lack of demand diversity introduced as a result of loss of supply – demands may be up to twice the typical forecast size with this effect expected to decay to 0 per cent increase after 30 minutes of supply restoration. The ADMS will only energise the demand block where this pre-calculated figure is below the DRZ-C estimated block-load pickup capability, which is continually refreshed. Should a block load be energised above the block load pickup capability, demand shedding can be used as a means of last resort by the fast balancing DRZ-C function. Slow balancing will then optimise the load sharing among all available resources to maintain headroom on the fast balancing service providers and enable repeated block loading to occur.

In Scotland, it is possible that a plan will require transmission energisation in order to complete the pre-block loading procedure. The transmission network energisation process should be followed before continuing power island growth.

When the DNO control engineer believes the power island is able to support transmission network energisation, it should notify National Grid Electricity System Operator (NGESO), who will assess the strategic benefits and readiness of the transmission network and instruct the next growth option. It is also possible that the DRZ procedure is not extended beyond the restoration of local demand. This still has clear benefits in meeting the Electricity System Restoration Standard for demand resupplied and may be synchronised to the transmission skeleton network at a later point in time.

Table 27: DNO change assessment for the DRZ growth phase

Area impacted	Changes required
Interfaces	The interface between the DRZ-C and DER are key at this stage. The DRZ-C system will also connect to the DMS and connected loads.
Systems	The DMS, DRZ-C and DERs systems are utilised at this stage.
Telecommunications requirements	The DNOs operational network which has been extended to the DER are in use. The functional requirement is also key for the network at this stage.
Training requirements	From this stage, there is a continued requirement for frequency management training as highlighted in the anchor generator stabilisation phase of the process, but there is also a requirement for knowledge of possible demands. The DRZ-C will seek DNO control engineer approval to switch in a block of demand that has the possibility to exceed the block load pickup capability of the power island. This decision will require manual demand forecasting supported by the DNO's individual demand forecasting systems and engineering judgement based off the responses seen which met the DRZ-C criteria for energisation. Therefore, training on both how to interact with the DRZ-C and how to manually forecast, including cold load pick-up effects, is a requirement for DNO control engineers. Familiarity with operating their networks and an enhanced requirement to forecast in normal business functions will support this training requirement. Furthermore, support tools including innovations such as SP Energy Networks' (SPEN's) will further improve this capability. (SPEN work with Sia Partners to forecast load at BSP level.) There is also a training requirement for assessing the optimal energisation strategy and making the decision between further network skeleton growth or commencing block loading. This was evident across desktop exercise discussions where debate was given to the priority of energising further demand ahead of further generation. This will vary for each specific plan and multiple options (as discussed in section 2.4) will be provided within the restoration plan in merit order in line with conventional restoration procedures.
Staff requirements	This phase of restoration will be similarly resource intensive to block loading in a conventional local joint restoration plan (LJRP) with an expectation that more than one control engineer will be needed to manage this process even with the support of automation. This is due to the need for monitoring performance, strategic decision making, demand forecasting and network energisation requiring approval stages.
Regional differences	In Scotland, it is possible that a plan will require transmission energisation in order to complete the pre-block loading procedure. The transmission network energisation process should be followed before continuing power island growth.

6.7.4 Distribution Restoration Service Provider

Top-up service providers will be required to maintain power resilience for communications and protection systems but not for all auxiliary systems required for generator starting. On receipt of a readiness to deliver service signal from the distribution network operator (DNO), the distributed energy resource (DER) will provide a status indication. Voice over IP communications will also be available if this is a manned site as an alternative mechanism. The service provider will wait for an instruction to join the power island at 0MW and close its generator circuit breaker. The DNO will then close the customer circuit breaker to energise the site. At this point, all auxiliaries should be powered, but the energy resource setpoint should be set at 0MW only providing local voltage support (where applicable) until issuing an availability signal to the DNO for fast balancing or slow balancing (where applicable). The DNO will then enable this distribution restoration zone controller (DRZ-C) function, and continuous setpoints will be issued to the generator site dependent upon the contracted service capabilities.

As demand is reconnected by the DNO, the DRZ-C will take fast balancing actions to re-dispatch generation or controllable demand in conjunction with direct anchor droop response to arrest the fall in frequency. Where the anchor is manually operated, an open voice over IP line will be established with a DNO control engineer in order to respond quickly to instability or issues with the generation unit. Slow balancing will then optimise the load sharing among all available resources to maintain headroom on the fast balancing service providers and enable repeated block loading to occur.

Table 28: DER change assessment for the DRZ growth phase

Area impacted	Changes required
Interfaces	The DNO interface to the DER network is required at this stage.
Systems	The DER interface system and the DRZ-C is used at this stage.
Telecommunications requirements	The DER operation will utilise the extended DNO operational network.
Training requirements	The DRZ-C will rely on pre-populated values for block load pickup capability and reactive range of generation, so training should focus on identification of any deviation from these values. Operators of manually controlled generation should be knowledgeable of anything which impacts on their rated block loading capability and inform the DNO through the DRZ-C. This includes identification and reporting of any stability issues noticed by the provider across the block loading process. This also exists for voltage support service providers across network and demand energisation processes. In both cases, a robust and assured automatic response and automatic flagging of stability issues is an alternative to this training.
Staff requirements	At this stage of the process, all DERs are required to maintain all resources required for service delivery for the duration of the restoration (up to five days).

6.8 Transmission Network Energisation

Transmission network energisation may occur before or after completion of distribution restoration zone (DRZ) growth dependent upon minimisation of the individual procedure’s technical risk or may involve direct synchronisation to an existing transmission level power island. This strategy will be pre-determined based on the mix of energy resources and demand sources available within the DRZ.

6.8.1 Electricity System Operator

As the national coordinator of restoration, National Grid Electricity System Operator (NGESO) is responsible for confirming readiness of all parties and instructing transmission network energisation. For the purposes of safety, the energisation process will be carried out over an open line between the distribution network operator (DNO) and the transmission network owner (TO). However, the overall national strategy must be considered at this stage as this process may change wider network restoration options or the sequence of transmission network skeleton growth.

Table 29: NGESO change assessment for the transmission network energisation phase

Area impacted	Changes required
Interfaces	NGESO will require interfaces to the TOs and DNOs at this stage. The Supervisory Control and Data Acquisition (SCADA), Inter-Control Centre Communication Protocol (ICCP) link and control telephone will provide these interfaces.
Systems	NGESO's, TOs' and DNOs' energy management systems will be utilised at this stage. The distribution restoration zone controller (DRZ-C) system and control telephone systems are also crucial at the stage.
Telecommunications requirements	The National Grid Operational network (OpTel), TO operational networks and DNO's operational network are utilised.
Training requirements	There are no new skills requirements introduced through this phase. However, assessing the network readiness for back energisation and coordinating the TO and DNO in this phase will need to be included in existing training.
Staff requirements	There is no resourcing impact for NGESO across this phase of restoration.
Regional differences	In Scotland, the TO can directly coordinate with the DNO without reference to NGESO for control due to their role as regional restoration leader.

6.8.2 Transmission Owners

On instruction to energise the transmission network from NGESO, the TO accepts responsibility to work directly with the DNO to achieve energisation. For safety purposes, direct contact is made with the DNO, and the TO should instruct energisation after confirmation of super grid transformer (SGT) isolation from the rest of the network. The SGT can be energised by the DNO, and on confirmation of stability of the power island, the transmission busbar can be energised. Further instruction on power island growth option will come from NGESO.

Table 30: TO change assessment for the transmission network energisation phase

Area impacted	Changes required
Interfaces	The TO SCADA interface and connection to the DNO network is required at this stage. Control telephone is also crucial to keep the line of communication open with the DNOs and NGESO at this point. The DRZ-C at the DNO network will require interface with the TO's for frequency data exchange.
Systems	The systems in use are the energy management systems for NGESO, TOs and DNOs. The DRZ-C system is also utilised for the energisation which will look to synchronise the DRZ and the transmission network. Phasor measurement unit (PMU) systems will exchange data with the phase measurement data in the DRZ-C.
Telecommunications requirements	The TO, DNO and NGESO operational networks are required at this stage. There is a telecoms requirement to allow exchange of frequency data between the TO and DRZ-C. This would use the existing infrastructure link (fibre) between the TOs and DNOs.
Training requirements	There are no new skills or capabilities introduced through this phase for DNOs. However, this new process of bottom-up transformer energisation needs to be incorporated into existing procedures.
Staff requirements	There is no resourcing impact for the transmission network owner (TO) across this phase of restoration.
Regional differences	In Scotland, the TO can directly coordinate with the distribution network operator (DNO) without reference to National Grid Electricity System Operator (NGESO) for control due to their role as regional restoration leader.

6.8.3 Distribution Network Operators

The DNO is responsible for establishing capability of the restoration zone to support transmission network energisation. Due to the inrush current from energising a super grid transformer (SGT), all top-up service providers which can support voltage should be energised in the previous stages. Connecting demand ahead of transmission energisation will dampen the voltage dip experienced, but dependent upon the resources within the group may lead to an unacceptable voltage dip that impacts on the connected demand. Specific guidance will be created for each power island as part of power systems studies during feasibility assessment. The DNO will inform NGESO, which will determine readiness of the national transmission system to support transmission level growth. The DNO will wait for instruction to energise the transmission system from the TO. For the purpose of safety, this will be carried out over an open line with the TO. The DNO will back energise the SGT, and the distribution restoration zone controller (DRZ-C) will monitor resources for stability enacting fast balancing or load shedding as a means of last resort in order to protect the anchor. The DNO may then assess if it has completed the DRZ plan; it may continue to grow the power island at distribution level without direction from NGESO if this is not completed.

Table 31: DNO change assessment for the transmission network energisation phase

Area impacted	Changes required
Interfaces	The distribution management system (DMS), DRZ-C will interface with the TO's network at this stage. Control Telephone interface to the TOs is also required at this stage. The DRZ-C at the DNO network will require interface with the TO's for frequency data exchange.
Systems	The DMS, TO's energy management system, DRZ-C, TO's phasor measurement unit (PMU), telephone systems will all be in use.
Telecommunications requirements	The DNO and TO operational networks will be critical at this stage. There is a new requirement to exchange frequency measurement data between the TO and the DRZ-C in the DNO's network.
Training requirements	This is a new process for DNOs with the inrush currents causing potentially large voltage deviations across SGT energisation. It is important that DNO control engineers are trained to understand if the resources are capable of this stage or should continue operating as a power island and wait for the transmission network growth from alternative DRZ or local joint restoration plan (LJRP). While the DRZ-C will provide feedback on stability and use fast acting, real and reactive response to contain the voltage swing, it will be a manually triggered process. The DRZ-C will not have data from the transmission network so cannot provide real-time guidance to control engineers.
Staff requirements	This process requires less control engineer intervention than the power island growth stage and is of a shorter duration but requires time for direct verbal communication with the TO and analysis of power island readiness to support the action.
Regional differences	In Scotland, the TO can directly coordinate with the DNO without reference to NGESO for control due to its role as regional restoration leader.

6.8.4 Distribution Restoration Service Provider

Across the transmission energisation process, top-up service providers and anchor DER may be issued setpoints by the fast balancing DRZ-C function. Voltage support will be provided by droop response from providers of the reactive support top-up service and the anchor DER.

Table 32: DER change assessment for the transmission network energisation phase

Area impacted	Changes required
Interfaces	The distributed energy resource (DER) system interface provided by the extended distribution network operator (DNO) network is crucial at this stage.
Systems	The distribution restoration zone controller (DRZ-C) systems and DER systems are in use at this stage.
Telecommunications requirements	The fast balancing action required at this stage means that it is important the network in use satisfies the functional specification. Low latency is required for this. The DNO's operational network extended to the DER is required at this stage.
Training requirements	There are no new training needs introduced for top-up service providers of the anchor service provider across this phase.
Staff requirements	Minimum staffing level to facilitate stable operation of the generation should be maintained for the duration of restoration (up to five days).

6.9 Power Island Growth

Power island growth may not be possible for all DRZs; dependent upon the resources within the zone, local demand restoration and synchronisation to an existing transmission power island may be required. However, where resources can support further network growth, this will be instructed by National Grid Electricity System Operator (NGESO), which may instruct further distribution level growth, synchronisation to a different power island or energisation of a transmission connected generator, inclusive of using the DRZ to provide auxiliary supplies; to achieve these, it may be necessary to energise the transmission system further. Energisation of transmission lines without load will lead to a significant increase in reactive power draw, which will be the limitation on power island expansion. For protection to operate at 400kV, energisation must include a 132kV connected fault infeed source.

6.9.1 Electricity System Operator

On notification that the DRZ is complete from the DNO, NGESO assumes strategic responsibility but does not resume frequency management until the point of connection to another energy resource outside of the DRZ. Dependent upon the regional restoration progress, it may instruct further distribution level growth, transmission network growth, energisation of the supplies for a transmission connected generator or synchronisation to an existing power island at transmission level.

NGESO may instruct the DNO to conduct further distribution power island growth; this would enable power available from the DRZ to block load further distribution network areas. As NGESO has not yet resumed frequency control, the DNO may independently conduct this process after instruction in line with conventional block loading.

NGESO may evaluate the readiness of the DRZ to support wider transmission network growth. This will make use of data exchange between the DNO and NGESO via Inter-Control Centre Communication Protocol (ICCP) for status monitoring of the power island. NGESO should verify this data and instruct the DNO to maintain a voltage setpoint at the transmission interface point. It should ensure the no-load reactive gain that will be experienced from energising the network option will not exceed the power island capabilities confirmed with the DNO and, following this, instruct the transmission owner to implement the restoration route, confirming with the TO that the network is appropriately isolated and not interconnected.

Instructing synchronisation to an external energy resource from the DRZ leads to implementation of the end condition for a DRZ.

Table 33: NGESO change assessment for the power island growth phase

Area impacted	Changes required
Interfaces	NGESO ICCP interface with the DRZ-C, control telephone interface to the DNOs and transmission network owner (TO) are utilised in this phase.
Systems	The energy management systems, DRZ-C and telephone systems are utilised at this stage.
Telecommunications requirements	NGESO operational network (OpTel) provides situational awareness to NGESO control engineers and the voice communication to ensure this activity is well coordinated. The DNO and TO operational networks are utilised at this stage.
Training requirements	From a control perspective, after assuming strategic responsibility, NGESO can treat the DRZ as a virtual power plant with visibility of the import and export capabilities of the power island provided via the Inter-Control Centre Communication Protocol (ICCP) connection resulting in enhanced visibility compared with conventional restoration providers. However, the introduction of a new strategic option for further distribution power island growth means this must be incorporated into the training programme.
Staff requirements	Real-time visibility of the capabilities of the distribution restoration zone (DRZ) aggregated capability may reduce strategic assessment time as compared with a conventional generator and so does not lead to an increased resource requirement.
Regional differences	The Scottish transmission network owner (TO) continues to maintain strategic responsibility across this phase regionally.

6.9.2 Transmission Owners

Across this stage, TOs are responsible for switching the transmission network to facilitate the instructed restoration route.

The Scottish TO can instruct all growth options within its licence area but cannot instruct energisation of transmission network or transmission connected providers in adjacent zones; should it require access to neighbouring areas, then National Grid Electricity System Operator (NGESO) must take responsibility for coordinating multiple network operators.

Table 34: TO change assessment for the power island growth phase

Area impacted	Changes required
Interfaces	The Supervisory Control and Data Acquisition (SCADA) interface within the TO's network and interface with the DNOs are crucial at this stage. Control telephone interface are required for coordination.
Systems	The TO's operational network, telephone system and phasor measurement unit systems will be in use at this stage.
Telecommunications requirements	The existing operational network will be in use with a requirement for exchange of frequency data if synchronisation with the distribution network is required.
Training requirements	There are no differences in the operating conditions for TOs under this stage of restoration.
Staff requirements	There are no differences in the operating conditions for TOs under this stage of restoration.
Regional differences	The Scottish TO continues to maintain strategic responsibility across this phase regionally.

6.9.3 Distribution Network Operators (DNOs)

DNOs to be responsible for the stable operation of the power island through control of energy resources within the zone. Fast balancing and slow balancing distribution restoration zone controller (DRZ-C) functions remain enabled and continue to ensure fast acting response to disturbances and slow acting response to continually reposition distributed energy resource (DER) and controllable load to maintain stability. However, NGESO will resume the role of strategic controller of the power island post completion of the predefined DRZ plan.

The DRZ-C will provide ongoing updates on the active and reactive power export capabilities of the power island through the 'virtual power plant' function. Fast balancing and slow balancing functionality remains active as the power island is expanded up until the point NGESO instructs the end of the DRZ.

If NGESO instructs further distribution power island growth, the DNO may independently determine the local strategy within its own licence area and energise further demand. The virtual power plant functionality of the DRZ-C will display the maximum available resources for block load, but this incremental growth outside of the pre-determined plan will be manually triggered. On connection to an external DER, NGESO may emergency instruct CUSC signatories where power resilient communications exist.

If NGESO instructs transmission network growth, it will confirm the reactive capability of the DRZ through use of aggregated DNO data transferred on the ICCP. NGESO will instruct the DNO on a voltage setpoint to maintain at the point of transmission connection. A DNO control engineer will trigger this function in the 'virtual power plant function' of the DRZ, which will issue voltage setpoint instructions to DERs within the power island in order to achieve this without introducing local issues. Energisation of the transmission system will cause a step change in reactive power as circuits are energised. Should this process cause instability as flagged by the DRZ-C stability monitoring, contact should be made with National Grid Electricity System Operator (NGESO) to abort the energisation process and review the power island growth strategy.

Table 35: DNO change assessment for the power island growth phase

Area impacted	Changes required
Interfaces	The Supervisory Control and Data Acquisition (SCADA) interface within the distribution network operator (DNO) operational network, distribution restoration zone controller (DRZ-C), transmission network owners (TOs) and NGESO for situational awareness are required. Inter-Control Centre Communication Protocol (ICCP) will provide the cross-party interface between the system. Voice communication interface is also required.
Systems	The distribution management system, DRZ-C and voice systems are in use.
Telecommunications requirements	The DNO, TO and NGESO operational networks will provide the data and voice communication requirements. Low latency network is required at this stage for fast balancing action.
Training requirements	Training will be required on the virtual power plant functionality of the DRZ-C. Given the complexity of conducting effectiveness calculations in real time, it is not recommended that this forms part of the manual procedure. If this condition arises due to failure of automation, the power island should be kept in a stable state and not grown outside of the DRZ boundary in order to maintain supplies to customers. Assuming automation does not fail, DNO control engineers must understand the limitations of the aggregated resources and agree with NGESO that the strategy does not compromise the existing DRZ operability.
Staff requirements	Fast balancing and slow balancing DRZ-C functions will continue to be enabled meaning that the DNO control engineer should not need to take direct action except to monitor the stability of the power island and agree strategy with NGESO. However, manually growing the power island at distribution level, which may be instructed by NGESO, is resource intensive requiring at least two operators for assessment of demand to be picked up and facilitating network access.
Regional differences	The Scottish TO continues to maintain strategic responsibility across this phase regionally.

6.9.4 Distribution Restoration Service Provider

Across the power island growth process, top-up service providers and anchor distributed energy resource (DER) may be issued setpoints by the fast balancing and slow balancing DRZ-C functions. Voltage support will be provided by droop response from providers of the reactive support top-up service and the anchor DER.

Table 36: DER change assessment for the power island growth phase

Area impacted	Changes required
Interfaces	The interface to the DRZ-C in the DNO network is required.
Systems	The DRZ-C systems and DER systems.
Telecommunications requirements	The DNO operational network extended to DER system is required.
Training requirements	There are no new training needs introduced for top-up service providers of the anchor service provider across this phase.
Staff requirements	Minimum staffing level to facilitate stable operation of the generation should be maintained for the duration of restoration (up to five days).

6.10 End of the Distribution Restoration Zone

The end conditions for the DRZ are connection to a generator which is not part of the pre-defined DRZ or connection to another power island. NGESO is responsible for the strategy including instructing a condition that triggers this end point. However, until National Grid Electricity System Operator (NGESO) instructs the end of the distribution restoration zone (DRZ), the distribution restoration zone controller (DRZ-C) control remains active, and the distribution network operator (DNO) remains in control of the overall power island frequency. On unwinding of DRZ-C automation, distributed energy resource (DER) will return to normal operational mode, and both droop control from the anchor DER and continuous setpoints from the DRZ-C will cease.

6.10.1 Electricity System Operator

Should NGESO determine that the national restoration strategy should involve connection to an energy resource not included within the restoration zone plan or synchronisation to another power island, this will trigger an end condition for the DRZ where NGESO assumes responsibility for the overall power island voltage and frequency. For either option, it should determine the maximum block load that the DRZ can support via the Inter-Control Centre Communication Protocol (ICCP) data connection.

To energise an additional energy resource, the procedure should be equivalent to conventional restoration. Contact should be established with the resource in order to enable emergency instructions to be followed. On confirmation that this resource has not experienced any issues from the unplanned loss of supplies, NGESO should instruct the transmission network owner (TO) (or distribution network operator (DNO)) to energise the auxiliary supplies for the generator if this is below the block load pickup capability of the power island. The energy resource will then provide a time to connect to NGESO, who will instruct the energy resource to prepare for block loading. The generator will be synchronised to the existing power island with free governor action. The DRZ will then be loaded with an additional block load which is lower than its block load pickup capability, and once frequency has stabilised, the newly connected energy resource will be despatched to a level equal to this block load. This process can be repeated for as long as the DRZ-C remains active with fast balancing being used to support the block loading process and slow balancing redistributing load to optimise the load sharing.

To synchronise to an external power island, an instruction should be issued from NGESO for the TO and the DNO to work together to enable synchronisation. On synchronisation to an external power island, the TO will confirm successful synchronisation, and NGESO will decide if it is appropriate to unwind the DRZ-C.

Table 37: NGESO change assessment for the end of the DRZ phase

Area impacted	Changes required
Interfaces	ICCP interface to provide NGESO situational awareness and voice communication is required at this stage.
Systems	The voice communication system, energy management systems and DRZ-C are in use at this stage.
Telecommunications requirements	The operational networks of NGESO, TOs and DNOs are utilised at this stage.
Training requirements	While connection of an additional generator which is not contracted for Black Start services will increase the overall block load pickup capability of the power island, only the known parameters for the DRZ-C should be used in initial stages as the newly instructed generation will not have been studied for block load pickup. As this DRZ-C capability is likely to be lower than conventional providers, training should reinforce this existing process requirement. NGESO control engineers require training to understand when it is appropriate to unwind DRZ-C automation. Fast balancing and slow balancing actions across the distribution level power island will support network stability but when a transmission connected generator is connected may have a negligible impact.
Staff requirements	There is no impact on required NGESO control engineers for this process as it mirrors existing power island growth from conventional providers with potential efficiencies in resource due to the visibility of real-time capabilities provided through the ICCP.
Regional differences	Scottish TOs can continue to grow the power island, inclusive of instructing non-contracted units within their licence area, until the point of synchronisation to a power island outside of their licence area.

6.10.2 Transmission Owners

NGESO will instruct either synchronisation to another power island or connection of another generator. If these actions take place on the transmission system, the TO will be responsible for enacting this.

If National Grid Electricity System Operator (NGESO) instructs connection to a generator, the transmission network owner (TO) will energise the generator auxiliaries, and on instruction, the generator will synchronise with the transmission network. The TO will await further instruction from NGESO.

If synchronisation is instructed, an open line between the TO and the distribution network operator (DNO) will be established. When the DNO confirms the synchronising mode is enabled in the distribution restoration zone controller (DRZ-C), the synchronising relay should be armed. The TO will inform the DNO to raise or lower the frequency such that they are very closely matched. The synchronising relay will then be armed in order to close when the frequency and phase angle are sufficiently small. On successful synchronisation, the TO will inform NGESO and await further instruction from NGESO.

Table 38: TO change assessment for the end of the DRZ phase

Area impacted	Changes required
Interfaces	This will require voice interface to NGESO and the DNOs. The DRZ-C could also require interface to the TO phasor measurement unit (PMU) for frequency data exchange if synchronisation is required.
Systems	The DRZ-C, energy management systems and voice communications systems are utilised at this stage.
Telecommunications requirements	The operational networks of the TO, DNOs and NGESO are required. The frequency exchange is a new requirement.
Training requirements	There are no new training requirements introduced through this phase. The responsibilities and capabilities of the TO mirror the conventional connection process. However, the change in interface from NGESO to DNO (as instructed by NGESO) should be covered in the training to enable the DRZ frequency to be matched closely enough to the synchronising power island to enable the synchronising relays to function. If synchronisation happens directly at the point of transmission connection, the DRZ-C may be able to use measurement data from a transmission side PMU to implement an automatic synchronisation function without use of a synchronising relay. This would represent a change to the proposed process and will be tested through Hardware in Loop (HiL) testing of the DRZ-C build stage.
Staff requirements	There are no resourcing requirements introduced in the TO for this phase of restoration.
Regional differences	Scottish TOs can continue to grow the power island, inclusive of instructing non-contracted units within their licence area until the point of synchronisation to a power island outside of their licence area.

6.10.3 Distribution Network Operators

NGESO will instruct either synchronisation to another power island or connection to another generator. It is possible that connection to another generator may be done at distribution level, which would be facilitated by the DNO.

If NGESO instructs connection to a generator connected to the distribution network, the DNO will energise the generator auxiliaries, and on instruction, the generator will synchronise with the distribution network. For both transmission and distribution connected additional generation units, NGESO will instruct the DNO to apply a block load to the DRZ within the overall capability rating provided by the DRZ-C. The newly connected generator will be instructed by NGESO to despatch to this same block load size. This action will provide headroom back to DRZ energy resources, which will enable further block loading. Further blocks of load should only be applied when instructed by NGESO.

If NGESO instructs synchronisation, the DNO will open a line with the TO. The DNO will enable the 'Resynchronisation function' in the DRZ-C. This will enable the DRZ-C to automatically vary the anchor distributed energy resource (DER) setpoint alongside the droop characteristic of the DRZ to align with the frequency and voltage of the external power island, where measurement data can be provided by the TO. Where measurement data cannot be provided, the TO will have visibility of both frequencies across the synchronising relay and may instruct the DNO to raise or lower voltage and frequency, which will be manually set as targets for the DRZ-C.

When instructed by NGESO to end the DRZ, the DNO will arm the restore network function within the DRZ-C. This will return the distribution network to its normal operating topology, restore protection settings groups, restore earthing and, when triggered by a DNO control engineer, disable fast and slow balancing capabilities and return the anchor generator governor back to constant power mode of operation.

Table 39: DNO change assessment for the end of the DRZ phase

Area impacted	Changes required
Interfaces	The distribution restoration zone controller (DRZ-C) interface to distributed energy resources (DERs) and transmission network owners (TOs) are required at this stage. The voice communication with NGESO and TO is also required for coordination.
Systems	The DRZ-C systems, energy management systems and voice communication systems are required.
Telecommunications requirements	The distribution network operator (DNO) operational networks, TO operational and National Grid Electricity System Operator (NGESO) operational network are all required. Voice communication will also be required for coordination.
Training requirements	While there are no new skills introduced at this point in the procedure, training on how to evaluate the power island capability when operating in virtual power plant mode will be required. As block loading will not be supported by the DRZ-C (outside of fast and slow balancing which remain in place), this will be a manual process in line with existing procedures for block loading a conventional provider. However, a real-time feed of the block load pickup capability of the island will be an output of the DRZ-C.
Staff requirements	This stage of network growth mirrors conventional restoration, but due to the requirement to continue to monitor the DRZ-C for stability, there is an additional resourcing requirement overall on the DNO control engineers.
Regional differences	Scottish TOs can continue to grow the power island, inclusive of instructing non-contracted units and the DNO within their licence area until the point of synchronisation to a power island outside of their licence area.

6.10.4 Distribution Restoration Service Provider

Across the power island growth process, top-up service providers and anchor DER may be issued setpoints by the fast balancing and slow balancing DRZ-C functions. Voltage support will be provided by droop response from providers of the reactive support top-up service and the anchor DER.

Table 40: DER change assessment for the end of the DRZ phase

Area impacted	Changes required
Interfaces	The DRZ-C interface to the DERs is required at this stage.
Systems	The DRZ-C system and the DER systems are required.
Telecommunications requirements	The DNO operational system which has been extended to provide communication infrastructure to the DER is utilised at this stage.
Training requirements	There are no new training needs introduced for top-up service providers of the anchor service provider across this phase.
Staff requirements	Minimum staffing level to facilitate stable operation of the generation should be maintained for the duration of restoration (up to five days).

6.11 Assessment of Time to System Restoration

Through applying the process design and reviewing the possible options for delivery, credible durations for restoration events have been compiled and reviewed. Each individual action has been given an estimated maximum duration as documented on the process map in Chapter 5. This has resulted from extensive consultation inclusive of desktop exercise outputs and consideration of DRZ-C automatic action. These findings are applied to the Chapelcross case study, following the desktop exercise approach. This provides a baseline example for developing a restoration zone end to end.

On applying this process design to the Chapelcross case study, it can be shown that there are six key time varying periods which align with the stages discussed across this section.

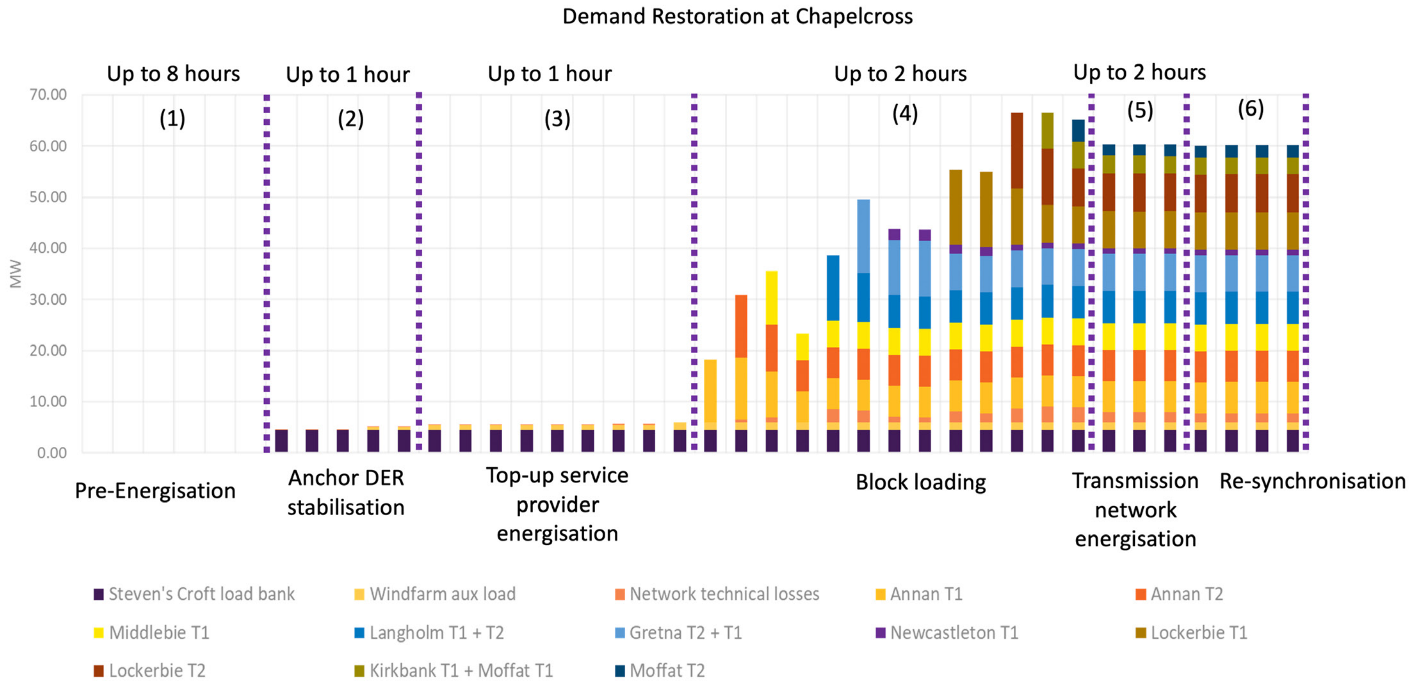


Figure 19: Indicative demand restoration timeline using reasonable worst case timings

6.11.1 Pre-energisation

The pre-energisation time period covers all actions that lead up to the anchor distributed energy resource (DER) providing the initial voltage source. In the process map, this covers Black Start declaration, information gathering, instruction of the distribution restoration zone (DRZ) and pre-energisation.

This stage involves a high degree of data exchange, preparation and verbal communications between all businesses. Under a reasonable worst-case condition, this leads to an eight-hour duration before any network is energised. This results from the functional specification which requires the anchor DER to be available within eight hours from notification of a restoration. However, procuring an anchor provider which can outperform this time to energisation would shift the limitation to the conventional information gathering and preparation activities, which may still take up to seven hours to deliver.

6.11.2 Anchor DER Stabilisation

This phase will be variable dependent upon the technology type delivering the service and may take up to an hour for a steam generator to ensure stable operation is achieved. This is considered as a reasonable worst case but may take significantly less time, dependent on the generator.

6.11.3 Top-up Service Provider Energisation

Energisation of top-up service providers is part of the DRZ growth stage of the process. It is estimated that each top-up service provider included within the zone may lead to a one-hour time to service provision, which if started sequentially would make this phase take three hours for the Chapelcross case study as a reasonable worst-case estimate. However, given the use of automation, non-sequential starting of top-up service providers could significantly decrease this time for restoration.

6.11.4 Block Loading

Block loading is part of the DRZ growth stage of the process. It is estimated that while it may only require minimal control engineer intervention to deliver the switching actions, a period of up to 30 minutes may be required to enable cold load pickup factors to dissipate. Therefore, an average worst-case time of 10 minutes per block load is used for estimating this duration. Chapelcross is split into 10 block loads leading to an approximate worst-case block loading period of 100 minutes. At this point in the process, there may be no further capacity for supplying further demand, so focus may be shifted to alternative restoration options in order to meet the Electricity System Restoration Standard criteria. The distribution restoration zone controller (DRZ-C) means that a stable power island can be maintained with minimum supervisory effort for the duration of sufficient fuel within the group.

6.11.5 Transmission Network Energisation

Coordinating the energisation of the transmission network is a manual process and may take up to two hours to deliver. This is due to the verbal communication required between different businesses and the more manual switching procedures that are typical at transmission voltages.

6.11.6 Synchronisation and End of the Distribution Restoration Zone (DRZ)

This process will be time-gated by the progress of other restoration zones and availability of alternative service providers. There is no specific time-based change introduced through Distributed ReStart.

6.12 Conclusion

The process design leads to change requirements across all organisations. However, the distribution network operator (DNO) is most impacted by this proposal with investment required to deliver new systems, telecommunications upgrades, more frequent and detailed training activities and potential changes to numbers of control staff if self-starting policies are not used. However, only the new capability of frequency management for the DNO, in the event of automation failure, is identified as an ongoing risk that is not mitigated directly through the proposal.

From the analysis of timing, while a plan requires up to 14 hours to deliver end to end, up to 8 hours of this time is derived from the initial information gathering and strategy analysis phase of the process. This has not deviated significantly from the findings in the design stage. This shows a marginal increase of approximately six hours to introduce each new DRZ if conducted sequentially.

7 Learnings for Roll-out

7.1 Introduction

As the final report in the series of organisational and procedural design publications, it is important to illustrate how these proposals can be effectively integrated into business procedures, consolidating learnings from across the project into clear but non-restricting recommendations for the organisations involved.

For this reason, this chapter will focus on the people side of change that will be introduced by a roll-out of Distributed ReStart. It will provide analysis of the likely impacts of integration with existing Black Start processes and procedures; any impacts, or synergies, observed with the wider transition towards active distributed energy resource (DER) participation in markets; and consideration of the ongoing development of distribution system operator (DSO) capabilities. The organisational impact assessment serves as an update to the discussion in the viability stage report, reviewing the design put in place and the key areas of change introduced. The review of processes, procedures and trainings will suggest the content, structure and any learning to be featured within future training. The systems, tools and data requirements section will review the functionality that will need to be installed to meet the procedural design and will reference published functional requirements but will not introduce any new specifications. Finally, the project will document the wider transitional changes in each organisation which provides either synergy or is in conflict with the proposed roll-out.

This report chapter is intended as a documentation of the requirements for implementation of the process for Distributed ReStart across each organisation. There will be some requirements that span different organisations involved leading to repetition; for this reason you may only wish to read the section relevant to the organisation in which you are most interested. This follows the same high-level change scoring system as the previous chapter illustrated through Table 41.

Table 41: High-level degree of change

Level of change	Score
No change is required; existing arrangements are capable of delivering this requirement.	Blue
A change is required, but this will not result in significant investment costs.	Green
A change is required, but this can be resolved through investment.	Amber
A change is required but this results in enhanced process risk.	Red

7.2 Electricity System Operator

7.2.1 Organisational Impact Assessment

Table 42: Organisational impact summary for NGESO

Area impacted	Current organisational requirements	Changes required
Interfaces	Transmission network owner (TO). Restoration Service Providers.	New interface with distribution network operator (DNO).
Systems	Integrated energy management system (IEMS), FATE. Voice communications.	New Inter-Control Centre Communication Protocol (ICCP) for situational awareness of distribution restoration zone controller (DRZ-C).
Telecommunications requirements	National Grid Operational network (OpTel).	Existing OpTel is suitable.
Training requirements	Yearly training.	Training frequency is suitable, but content needs to include distribution options.
Staff requirements	129–133 authorised engineers.	Joint training with distribution network operator (DNO), transmission network owner (TO) and providers is recommended biennially.
External factors	The wider impacts of meeting the Electricity System Restoration Standard (expectation of 60 per cent demand restoration within 24 hours implemented regionally and 100 per cent restoration within 5 days) will result in a more significant change than a distribution level option. Procedures which do not require transmission access and restore local demand only may be more beneficial in mitigating the wider requirements on the number of concurrent plans National Grid Electricity System Operator (NGESO) may need to operate as most manual interaction is limited to growth beyond the distribution/transmission boundary.	

7.2.2 Processes, Procedures and Training

All of the key change requirements identified for NGESO are adaptions required to the training process. In particular, NGESO control engineers need to have sufficient understanding of a distribution level approach to restoration and when and how to incorporate these into the wider transmission network restoration strategy. Furthermore, more active joint exercises between NGESO, transmission network owner (TO) and distribution network operators (DNOs) is strongly recommended. The present NGESO control training unit cannot simulate the distribution network adequately to facilitate cross-industry input on a common platform. This limitation means that it is recommended the joint biennial trainings use a different simulation platform for Distributed ReStart.

The future integrated energy management system (IEMS) digital twin will allow for very detailed NGESO training requirements to be met, and it is not recommended that Distributed ReStart leads to any difference in this future method of internal training. It will be important that active distribution restoration zone controllers (DRZ-Cs) are modelled as part of this process and tested alongside conventional local joint restoration plan (LJRP) options. For this reason, no substantial change is required to the standard training methodology employed by NGESO.

For joint training, it is recommended that a software platform is used that allows all parties to actively participate. The desktop exercise platform developed is an example of this but is also not fit for purpose for an enduring training platform due to its lack of dynamic data and inability to introduce failure modes. Options for further development of this platform for future training are provided in section 4.2.7, and if these were implemented, then this provides a low-cost, virtual method of bringing all different parties onto a single platform.

7.2.3 Systems, Tools and Data Requirements

The only change proposal made for NGESO systems is the introduction of an Inter-Control Centre Communication Protocol (ICCP) with mapping of data points between the DNO distribution management system (DMS) and DRZ-C providing the enhanced situational awareness needed.

Specifically, feedback from desktop exercises has demonstrated a desire for access of state of readiness information from the DRZ-C, duration of fuel/charge available to the DRZ-C, current status of the restoration (aggregated at 33kV and 132kV level), power available, reactive power available and approximate time to transmission connection. Where available as an output of the DRZ-C, these should be passed via the ICCP connection to the advanced distribution management system (ADMS). Where unavailable, verbal communication with the DNO will be used to identify these key strategic data points. However, no need has been identified for a DRZ-C to be actively controlled by NGESO, so this data is entirely for visibility, and no active control capability is needed in the ICCP implementation for Distributed ReStart.

7.2.4 External Factors

The first Distributed ReStart procedures are planned, where economic, to be delivered within RIIO-2 timelines. The project has reviewed and consulted on these internal change processes, inclusive of regional development plans, future integrated energy management system and future balancing programme work.

The ICCP link required for Distributed ReStart is also utilised in regional development plan requirements and for the power potential service. This synergy, alongside a general need for greater situational awareness of distribution level resources and networks, means that Distributed ReStart is one of multiple use cases for necessary system change across NGESO as a whole.

A key and current change that is undergoing consultation is the role of a fully independent future system operator. This may no longer be part of the National Grid group, involving a new legal structure but also an undertaking for the organisation to deliver against more roles. However, as this process design already fully aligns with legal separation and considers use of a future separated IEMS, there will be limited impact outside of accountability for the actions of NGESO being moved to a future system operator. Furthermore, at this stage, a review of any distribution system operator (DSO) capabilities has been deemed out of scope of this review process, so there should be no impact on the proposed roles for DNOs in this process design.

7.3 Distribution Network Operator (DNO)

7.3.1 Organisational Impact Assessment

Table 43: Organisational impact summary for DNOs

Area impacted	Current organisational requirements	Changes required
Interfaces	Transmission network owner (TO).	The DNO now interfaces with National Grid Electricity System Operator (NGESO). The DNO now interfaces with distributed energy resource (DER) (via distribution restoration zone controller (DRZ-C) and voice communication).
Systems	Advanced distribution management system (ADMS) (with group telecontrol typically used for block loading).	New group telecontrol sequences added to ADMS. DRZ-C which meets the functional specification. New Inter-Control Centre Communication Protocol (ICCP) link with NGESO.
Telecommunications requirements	At least biennial training.	Upgraded, power resilient communications network which meets the functional specification.
Training requirements	Two control engineers minimum.	At least yearly training. Active participation in cross-industry training at least biennially. Desktop exercises conducted with DER participants. Internal specific DNO training on use of the DRZ-C system.
		Frequency control capability as a redundant requirement i.e. DNO's ability to manage the frequency as a backup option if automation fails.
Staff requirements	Two control engineers minimum.	No specific change to minimum staffing but an enhanced reliance on called-in resources in the control room due to involvement earlier in the process. At least two control engineers should be involved in distribution restoration zone plan (DRZP) management For this reason, where a DNO has multiple DRZP and local joint restoration plan (LJRP) options in their there may be a need for increased minimum resourcing or prioritisation based on staff constraints while further control engineers are called to site.
Other considerations	While managing a DRZ is a step change in the organisational capabilities of DNOs for restoration, it is in line with the developing distribution system operator (DSO) capabilities reducing the organisational burden of these changes. Future DRZ-C systems and their interface with the DER have many synergies with active network management schemes, and the functional specification may be integrated into these methods used for management of distribution networks. It should also be recognised that without Distributed ReStart implementation, DNOs will have a greater role to play in electricity system restoration as part of the roll-out of the new Electricity System Restoration Standard.	

7.3.2 Processes, Procedures and Training

The current electricity system restoration training frequency and quality will need to be increased for DNO control engineers to reflect the increased responsibility which they take in this new operational procedure. It is recommended that a training frequency and style similar to National Grid Electricity System Operator (NGESO) is adopted. This will lead to annual internal training for all control engineers on distribution restoration zone (DRZ) using the specific implementation of active network management (ANM) system and distribution restoration zone controller (DRZ-C) functionality and user interface which they have selected for roll-out. This should focus on how the specific network area is restored, variability within this plan and procedure, redundancy for failure modes and any methods used to bring additional control engineers to site under periods of minimum staffing.

In addition to this yearly training, biennial cross-industry training is recommended including all key parties involved in active DRZ plans. For joint training, it is recommended that a software platform is used that allows all parties to actively participate. The desktop exercise platform developed is an example of this but is also not fit for purpose for an enduring training platform due to its lack of dynamic data and inability to introduce failure modes. Options for further development of this platform for future training are provided in section 4.2.7, and if these were implemented, then this provides a low-cost, virtual method of bringing all different parties onto a single platform.

Frequency management capability is singled out as a procedure which will not be undertaken by DNOs under normal network conditions. It is unlikely that frequent use of this capability would be made by distribution network operators (DNOs) under any distribution system operator (DSO) services as national frequency would be maintained outside of islanded operation. Furthermore, even very high-quality, regular training will not mitigate against the risk of a DNO control engineer exercising this capability for the first time under an emergency restoration scenario. For this reason, it is a critical aspect of the DRZ-C, and the DNO should always prioritise procedures with a functional DRZ-C system. The focus for mitigation of this risk is on the inclusion of robust disaster recovery and resiliency within the DRZ-C design. However, manual training should also be given so a DNO control engineer may grow a power island in the event of automation failure as a means of last resort. This will substantially increase the risk of instability to the power island but could not be mitigated outside of NGESO direct control of distributed energy resource (DER) output, which would result in a far more significant overall change impact than the proposed solution. Options that have been suggested for this training method include shadowing NGESO control engineers responsible for frequency management and generator dispatch, but this is still inadequate for providing a high degree of competence in this function.

7.3.3 Systems, Tools and Data Requirements

The DNO has the most change of any organisation to the systems, tools and data requirements principally through the introduction of a new, power resilient, low latency communications network which is extended out to DER sites involved in a DRZ. This network upgrade process may be offered for new connections but is only anticipated to be rolled out where there is an active DRZ-C in order to minimise the costs introduced for restoration. The functional specification is undergoing further review in order to ensure it meets the cyber security and latency requirements of a proven DRZ-C design. However, the current understanding of these operational communications requirements is summarised in Tables 1-8 in the Organisational, Systems and Telecommunications design report part 2: **nationalgrideso.com/document/182841/download**

The next key system introduced is the DRZ-C. This will place a reliance on enhanced group telecontrol from the advanced distribution management system (ADMS) as well as new ANM-like infrastructure. A final design is undergoing design and build for Hardware in Loop (HiL) testing at the National HVDC Centre and will result in an updated functional specification. However, the draft functional requirements are documented on pages 7-59: **nationalgrideso.com/document/182481/download**

In order to ensure that the design remains vendor agnostic and that DNOs and future system integrators have a variety of design options, the front-end engineering designs from four vendors were commissioned and have been published. The project intentionally does not make a recommendation on the system integrator to be used as this should be procured as part of a competitive tender event. General Electric's design has been progressed through to the final build and testing phase as a result of a project internal tender process. The design choice for each DNO will be specific to pre-existing systems that this capability may be integrated with the specific combination of energy resources and networks involved.

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Smarter Grid Solutions
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ZIV Automation
nationalgrideso.com/document/204671/download

7.3.4 External Factors

The first Distributed ReStart procedures are planned, where economic, to be delivered within RIIO-ED2 timelines. Distribution network operators (DNOs) have submitted their RIIO-ED2 plans, which means that any required changes from this process will be facilitated either by re-openers or a procurement mechanism. The specific funding methodology will be explored in a later report due for publication by the Procurement and Compliance workstream in December 2021.

The wider change from passive operators of distribution networks to active distribution system operators (DSOs) is a key synergy identified with the organisational approach taken. We have ensured that this work is aligned with the outputs of the Energy Networks Association (ENA) Open Networks project least regrets worlds inclusive of consultation with this group across all workstreams.

The Inter-Control Centre Communication Protocol (ICCP) technology required for Distributed ReStart is also utilised in regional development plan requirements and for the power potential service. This synergy, alongside a general need for greater situational awareness of distribution level resources and networks, means that Distributed ReStart is one of multiple use cases for necessary system change for all DNOs.

7.4 Transmission Owner (TO)

7.4.1 Organisational Impact Assessment

Table 44: Organisational impact summary for TOs

Area impacted	Current organisational requirements	Changes required
Interfaces	National Grid Electricity System Operator (NGESO). Distribution network operator (DNO). Restoration service provider.	No change in E&W. For Scotland, where there is a need for interface with transmission connected energy resources within a distribution restoration zone (DRZ).
Systems	Integrated energy management system (IEMS) National Grid Electricity Transmission (NGET). Transmission management system.	No change in E&W. For Scotland, elements of the distribution restoration zone controller (DRZ-C) may be installed at transmission level (132kV).
Telecommunications requirements	National Grid Operational network (OpTel) or Scottish transmission communications network.	There may be a requirement for transmission phasor measurement unit (PMU) data to be exchanged with the DNO in order to enable synchronisation functionality.
Training requirements	At least biennial training.	At least biennial training adapted for specific DRZ options.
Staff requirements	Two to five control engineers minimum.	No change required.
External factors	Scottish TOs have an enhanced role in this restoration process compared with E&W TOs, but this is in order to ensure alignment with pre-existing network codes. It should also be recognised that without Distributed ReStart implementation, TOs will have a greater role to play in electricity system restoration as part of the roll-out of the new Electricity System Restoration Standard.	

7.4.2 Processes, Procedures and Training

Scottish TOs do not experience a significantly enhanced role through Distributed ReStart, and as a result the proposed training requirements are not substantial. The existing joint NGESO training is sufficient to maintain operational understanding for restoration capability at both transmission and distribution level assuming minor adaptions to this training to incorporate aspects of the DRZ design.

In addition to this biennial joint training with NGESO, biennial cross-industry training is recommended including all key parties involved in active DRZ plans. For joint training, it is recommended that a software platform is used that allows all parties to actively participate. The desktop exercise platform developed is an example of this but is also not fit for purpose for an enduring training platform due to its lack of dynamic data and inability to introduce failure modes. Options for further development of this platform for future training are provided in section 4.2.7, and if these were implemented then this provides a low-cost, virtual method of bringing all different parties onto a single platform.

7.4.3 Systems, Tools and Data Requirements

The key additional data transfer and systems requirement for National Grid Electricity Transmission (NGET) is a potential requirement for phasor measurement unit (PMU) frequency data exchange to facilitate the synchronisation. This may require implementation of a data exchange link passed via National Grid Electricity System Operator (NGESO) Inter-Control Centre Communication Protocol (ICCP) or could be facilitated by direct connection.

For the Scottish transmission owners (TOs) there may be a requirement to implement distribution restoration zone controller (DRZ-C) functionality. This system is still intended to be owned and operated by the distribution network operator (DNO) but dependent upon the technology employed may require physical hardware to be installed in the TO network and confirmation of state signals to be provided from the transmission system to the DRZ-C. As these only exist in Scotland, this solution is considered acceptable due to the joint ownership of transmission and distribution functions by the same business entities. A final DRZ-C design is undergoing design and build for Hardware in Loop (HiL) testing at the National HVDC Centre and will result in an updated functional specification. However, the draft functional requirements are documented on pages 7-59: **nationalgrideso.com/document/182481/download**

In order to ensure that the design remains vendor agnostic and that DNOs and future system integrators have a variety of design options, the front-end engineering designs from four vendors were commissioned and have been published. The project intentionally does not make a recommendation on the system integrator to be used as this should be procured as part of a competitive tender event. General Electric's design has been progressed through to the final build and testing phase as a result of a project internal tender process and does not mean that this provider is required for use by DNOs GB wide. The design choice will be specific to pre-existing systems that this capability may be integrated into and the specific combination of energy resources and networks involved.

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7.4.4 External Factors

Should a change of ownership structure happen, splitting the TO and DNO networks in Scotland between different businesses, this would require specific investigation of the correct future ownership and operational structure for a DRZ-C. It is likely that 132kV network access will be required for some successful DRZ options. However, this would be one element within a large change programme as the networks are operationally closely interconnected so this is not specifically reviewed by this project.

7.5 Distributed Energy Resource Operator

7.5.1 Organisational Impact Assessment

Table 45: Organisational impact summary for DERs

Area impacted	Current organisational requirements	Changes required
Interfaces	N/A	A new interface with the DRZ-C and resilient data and voice over IP DNO communications will be introduced.
Systems	Dependent on technology type.	It is anticipated that delivery of a contracted anchor or top-up service will require the distributed energy resource (DER) to install new equipment to deliver the service. This will include direct response to DRZ-C instructions. However, this upgrade would be funded as part of service provision.
Telecommunications requirements	Limited non-power resilient operational communications with distribution network operator (DNO) (in some instances), mobile phone or teleoperated assets with a central control room function that may be abroad are common.	The telecommunications requirements must meet the functional specification.
Training requirements	Dependent on technology type, many sites are unstaffed and use third-party contractors so will not have a training process.	The distributed energy resource (DER) must demonstrate a robust training process for restoration capability or a resilient automated response to distribution restoration zone controller (DRZ-C) input signals. This will form part of assurance requirements.
Staff requirements		A minimum staffing requirement should be maintained so that availability information can be provided at all times and that the contracted service can be delivered within eight hours of instruction. For service delivery, any contractor, called-in resource or self-starting organisational structures used must ensure that staff are dedicated to the specific provider in the event of restoration and that it does not compromise the overall ability of the energy resource to deliver the contracted service within eight hours.
External factors	The current arrangement for DERs will be extremely variable dependent on the technology, the scale and the businesses which operate them.	

7.5.2 Processes, Procedures and Training

Where authorisations for control engineers exist, this must form part of the process. It will be included within assurance requirements for all service providers where applicable. Where remotely or automatically controlled, it must be demonstrated that these procedures are robust and power resilient through assurance activities.

7.5.3 Systems, Tools and Data Requirements

The DER is responsible for connection from the DNO point of connection to its control system, inclusive of ensuring power resilience and any latency requirements for the specific service provision are delivered. If remotely operated and requiring supervision from a central control function to deliver the service, it is the responsibility of the DER to install this capability. Any required telecommunications to meet the procured service must be power resilient for at least 72 hours and will form part of the assurance requirements.

7.5.4 Integration with Wider Business Activities

Ongoing work is seeking to make the distribution restoration service fully stackable with all other services. As the power market is suspended for the duration of service provision, there should not be an impact on this. The integration with the DRZ-C is analogous to active network management (ANM) roll-out, which is ongoing and makes use of similar interface structures.

7.6 Approach to Change Management

In 1995, John P. Kotter published his seminal work 'Leading Change: Why Transformation Efforts Fail'. This paper cited research that suggested only 30 per cent of change projects succeed in meeting their aims and objectives. If we fast-forward to today, there are many articles on change management success rates which still demonstrate the same 30 per cent success rate, so not much has changed in the past 26 years, it seems! One of the main reasons for this situation is that most change management models have sometimes ignored the irrational thought-processes and behaviours of people involved in the change, either as managers or employees impacted. Change only happens in organisations when people themselves accept the need for change and adapt their behaviours accordingly.

Within National Grid ESO, we have adopted the Programme and Change Management Business Management System (BMS) Standard, which, in turn, supports the Agile Change Delivery Framework. For business change management, this involves the proactive identification and management of the impact of changes on people, process and technology. Monitoring the change environment and ensuring those impacted by change have bought into the vision of the programme, during programme delivery, is critical to the sustainment of the changes and to delivering programme benefits.

For this reason, this section will focus on the people side of change that will be introduced by a business as usual (BAU) roll-out of Distributed ReStart, across three dimensions:

- Organisational Impacts
- Processes and Procedures
- Systems and Tools.

In addition, we have considered the likely impacts around integration with existing restoration processes and procedures and how this will have to adapt to allow for a complementary Distributed ReStart service to co-exist alongside, not only transmission-connected restoration services, but other services that the same distribution-connected resources provide (or will provide in the future) under normal electricity market conditions (e.g. balancing, constraint, resilience, inertia and so on).

Finally, we highlight the key changes that a distributed energy resource (DER) would need to consider in order to be successful in contracting for a Distributed ReStart service, either as an anchor generator or top-up service provider.

7.6.1 Key Organisational Impacts

From a people perspective, the resourcing requirements on distribution network operators (DNOs) are mitigated by the introduction of automation, and it is expected that one DNO control engineer will be capable of managing a single distribution restoration zone (DRZ) inclusive of loading the anchor to a stable operating position. However, with familiarity and increased levels of training and confidence in automation, a DNO control engineer may manage multiple islands in parallel, allowing stable operation to be maintained by the DRZ-C. This is not recommended for initial roll-out but mitigates against an exponential engineering requirement.

From a DER perspective, the anchor DER is required to have sufficient engineering resource to deliver against this requirement within eight hours of instruction (from the lead DNO) to the point of energisation. This also applies to any top-up service providers from the point of DRZ instruction.

As Distributed ReStart will be the first process to require this capability within DNOs under an emergency condition, it is essential that training focuses on this specific capability despite the support received through automation.

7.6.2 Processes and Procedures

It is clear from the findings of our three desktop exercises, and the subsequent stakeholder reviews and feedback, that DNOs need to be fully aware of their new responsibilities under a Distributed ReStart scenario. In particular, the requirement to take on the role of managing frequency during the anchor DER stabilisation phase and manage the interactions between DNO and DER (e.g. issuing of emergency instructions after the declaration of Black Start by the NGESO and the subsequent information-gathering stage).

In addition, National Grid Electricity System Operator (NGESO) and transmission network owner (TO) engineers will have new situational awareness capability, via Inter-Control Centre Communication Protocol (ICCP) links and the distribution restoration zone controller (DRZ-C) automation proposed by our functional designs, although any major changes to the existing restoration processes and procedures are minimised by the application of the central model, as previously mentioned. It is interesting to note that the new requirement on the DNO to manage frequency during the anchor DER stabilisation and subsequent power island growth stages represents a 'letting go' of existing NGESO/TO responsibilities, and this was widely discussed and commented on during the desktop exercises.

7.6.3 Systems and Tools

In terms of systems, such as integrated energy management system (IEMS), active network management (ANM) and distributed energy resources management System (DERMS), we have analysed the likely impacts to these systems and highlight where changes will be required to support a Distributed ReStart service. A benefit of the central model is to minimise these impacts where it makes sense to maintain the existing systems and processes or augment them as required. It's fair to say that the main impacts to systems will be at the distribution level, where there is a requirement for a new control system to be introduced which mitigates against a higher resource requirement.

Communications are a major consideration, particularly for the power-resilient and cyber-secure links that will be needed between the DNO and any DER assets contracting for Distributed ReStart services, as well as upgraded ICCP links between DNOs and the NGESO IEMS system, where required. Therefore, existing communications for voice and data will need to be upgraded to meet our design specifications, particularly around power and cyber-resilience requirements for distributed generation assets sitting outside of the National Grid OpTel network. For example, an extension to the existing power resilient distribution network operator (DNO) communications network will be required to the distributed energy resource (DER) site. This will only apply to contracted providers to minimise the cost requirements.

7.7 Next Steps

In considering the next steps, we have assumed that not all key decision-makers across the impacted organisations are fully aware of all the changes needed to successfully implement a Distributed ReStart capability into their organisation. To this end, we would like to emphasise that use of a holistic, people-centred approach to change management be adopted by each organisation. By way of illustration, NGESO's Business and Change Management function mandates the following steps on any change programme that we deliver internally:

- Ensure the vision, purpose and benefits of the programme are clearly outlined in a case for change.
- Ensure that key business stakeholders and groups impacted by the programme's changes are engaged and involved throughout the programme.
- Perform a change impact assessment to identify where, how, when and to what degree the change(s) will impact the business.
- Consider if any impacts will affect internal controls, financial reporting and legal or regulatory compliance processes, and be sure they are clearly accounted for and addressed within programme action plans.
- Assess the communications needs of the programme, and then develop and implement a communication plan, including supporting materials, to inform the business and key stakeholders of the upcoming changes.
- Ensure that all change impacts have robust mitigation and action plans, e.g. training, to ensure a smooth implementation.
- Prior to launching changes, assess how prepared impacted stakeholders are for the upcoming changes by conducting a business readiness assessment, and then adjust implementation plans accordingly.
- Define and implement activities that will enable the business to embed the new ways of working that will realise programme benefits.
- Ensure that the enduring solution is effectively handed over to the business and that there is a clearly defined product owner.

As a project, we will engage with all impacted organisations, but will initially focus on the DNOs, as they are the most impacted by this new restoration process, and there is a need to ensure that their RIIO-ED2 plans for 2023–28 reflect any additional funding that may be required, or at least provide for a re-opener mechanism that allows for funding to be provided if and when it is needed. Our approach, therefore, is to further create DNO awareness via a restoration roadshow (includes the change impact assessment and training needs analysis) to cover our recommendations around required change impacts in Table 46 below:

Table 46: Changes resulting from the Distributed ReStart process design

Organisation	Area impacted	Changes required
Transmission Owner	Interfaces	No expected changes in England and Wales. For Scotland, where there is a need for interface with transmission connected energy resources within a distribution restoration zone (DRZ).
	Systems	No expected changes in England and Wales. For Scotland, elements of the control system may be installed at transmission level (132kV).
	Telecommunications requirements	There may be a requirement for transmission phasor measurement unit (PMU) data to be exchanged with the DNO in order to enable synchronisation functionality.
	Training requirements	At least biennial training adapted for specific DRZ options.
	Staff requirements	No change required.
NGESO	Interfaces	New interface with DNO.
	Systems	New Inter-Control Centre Communication Protocol (ICCP) for situational awareness of distribution restoration zone controller (DRZ-C).
	Telecommunications requirements	Existing National Grid Operational network (OpTel) is suitable.
	Training requirements	Training frequency is suitable, but content needs to include distribution options. Joint training with distribution network operator (DNO), transmission network owner (TO) and providers is recommended biennially.
	Staff requirements	No change required.
DNO	Interfaces	The DNO now interfaces with National Grid Electricity System Operator (NGESO). The DNO now interfaces with distributed energy resource (DER) (via DRZ-C and voice communication).
	Systems	New group telecontrol sequences added to advanced distribution management system (ADMS). DRZ-C which meets the functional specification. New ICCP link with NGESO.
	Telecommunications requirements	Upgraded, power resilient communications network which meets the functional specification.
	Training requirements	At least yearly training. Active participation in cross-industry training at least biennially. Desktop exercises conducted with DER participants. Internal specific DNO training on use of the DRZ-C system. Frequency control capability for redundancy to automation. Frequency control capability for redundancy to automation.
	Staff requirements	No specific change to minimum staffing but an enhanced reliance on called-in resources in the control room due to involvement earlier in the process. At least two control engineers should be involved in distribution restoration zone plan (DRZP) management. For this reason, where a DNO has multiple DRZP and local joint restoration plan (LJRP) options in their there may be a need for increased minimum resourcing or prioritisation based on staff constraints while further control engineers are called to site.

Organisation	Area impacted	Changes required
DERs	Interfaces	A new interface providing resilient data and voice over IP DNO communications will be introduced.
	Systems	It is anticipated that delivery of a contracted anchor or top-up service will require the DER to install new equipment to deliver the service. This will include direct response to distribution restoration zone controller (DRZ-C) instructions. However, this upgrade would be funded as part of service provision.
	Telecommunications requirements	The telecommunications requirements must meet the functional specification.
	Training requirements	The distributed energy resource (DER) must demonstrate a robust training process for restoration capability or a resilient automated response to DRZ-C input signals. This will form part of assurance requirements.
	Staff requirements	A minimum staffing requirement should be maintained so that availability information can always be provided and that the contracted service can be delivered within eight hours of instruction. For service delivery, any contractor, called-in resource or self-starting organisational structures used must ensure that staff are dedicated to the specific provider in the event of restoration and that it does not compromise the overall ability of the energy resource to deliver the contracted service within eight hours.

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9 Appendix 1: Stakeholder Questions

9.1 Desktop Exercises

Table 47: Questions and answers from the desktop exercises

Question	Response
Process thought – do we have a process set up to get a Black Start declaration onto the balancing mechanism reporting system (BMRS), and do all parties who need to see it have access/monitor ?	There is a process; however, all parties may not have access as they may not have power during the outage. Only those with independent power resilience during the outage will see the notifications.
Do the operators need details of any battery/converter systems to be able to judge power and reactive power capacities, energy capacities, SC contribution?	As part of a restoration zone plan, the capability of all energy resources included would be provided. Post black-out there is a requirement to establish any deviation from this capability when assessing the overall distribution restoration zone (DRZ) ability to restore the network.
Step 10. If 'power available' signal is available from distributed energy resources (DERs) over Supervisory Control and Data Acquisition (SCADA), this could be aggregated by distribution restoration zone controller (DRZ-C) to report as block. Storage MWh also.	Local controllers would collect such information, and this will be passed on to the distributed controller as part of the DRZ-C function.
When the blackout is established, how would the relevant parties know that the network was intact prior to carrying out the restoration?	The parties would use the available monitoring systems (distribution management system (DMS)/ integrated energy management system (IEMS)/Supervisory Control and Data Acquisition (SCADA) to check prior to restoration. It is assumed that restoration participants have independent power resilience, and hence the systems would be available.
The pre-restoration state still has quite a few breakers closed. Is that deliberate?	Pre-energisation, the network should be switched without load to minimise the switching actions which achieve the pre-agreed restoration routes. This reduces the likelihood of a fault. For this exercise, this network is pre-configured.
Is it higher priority for DRZ to energise customers within zone, or to provide capacity to wider restoration? If MW limited, there may be a choice between them.	The newly introduced Electricity System Restoration Standard (Introducing a new 'Electricity System Restoration Standard': policy statement – GOV.UK (www.gov.uk)) sets a target on customer demand restoration within 24 hours. Restoration zones would be procured to enable delivery of this standard. Each zone will have a set of pre-defined restoration options for operators to choose, dependent on the specific generator and network conditions at the time of restoration. The technical capabilities of the zone will determine if it is best to connect demand first or to energise a greater proportion of the network ahead of restoring demand.

Question	Response
Not everyone is familiar with the plans in place, which is fine for the exercise. But it makes me wonder how this would play in reality where some actors may well have forgotten plans if they are not often called on to enact the plans. Different for some staff if exercise is used as refreshers.	Operators (distribution network operator (DNO), transmission network owner (TO), National Grid Electricity System Operator (NGESO)) receive at least biennial training for existing restoration procedures. Additionally, restoration service providers must demonstrate adequate training and familiarity through assurance visits. Introduction of this new service will require extensive training for the control engineers. Recommendations for training have been made in this report, taking learnings from the desktop exercises to support development of requirements.
The speed of information exchange/ responsiveness may need to take account of the confidence of the supply availability, i.e. variable over time.	Power resilient, suitably specified operational telecommunications are a key deliverable to support network restoration using distributed energy resource (DER). A functional specification has been developed and will be refined through further control system development and cyber security requirements development.
What mode are these wind farms in? They have 12 MW available but supplying only reactive power. Are they switched to grid-forming mode? Is that in the procedure?	Some wind farms can operate at a 0MW setpoint and provide reactive control through on-site compensation, while others may rely on wind availability to provide this service. In the desktop exercise, we assume operation in voltage control mode to support reactive requirements of the lightly loaded network. Active power setpoints are issued independent from this voltage control mode to wind farms across the exercise. For real service providers, the capability to provide reactive power may be variable across the reactive power range, and this should be considered in the development of restoration procedures.
Didn't catch whether wind farm energising decision is the responsibility of NGESO or DNO?	The responsibility for the operation and instruction of active and reactive power setpoints or modes of generator operation is that of the DNO within the pre-agreed network area. Outside of the network area which forms the restoration zone, NGESO would be responsible for issuing instructions to generators directly where power resilience of communications exists. This may be done via a DNO instruction on behalf of NGESO, dependent on the generator scale.
Several questions about synchronisation: how is it achieved? Is there check dead protection for energising without synch? What about race conditions between two DR zones? How does a generator know if it's to close onto a dead circuit or wait for a live one and synchronise to that?	Synchronisation will be achieved at pre-determined locations and will involve similar processes to what is currently done with larger power stations, including the use of synch-check relays and careful control of the frequency and voltage on each side of the synchronising point. There will be restoration readiness build requirements for DER and network areas providing the Distributed Restart service like conventional restoration providers. Where further infrastructure is needed, this would be delivered as part of this build process.
Does the DNO need to wait for the NGESO to decide what to do? Or might some distribution restoration zones (DRZs) be established independently of NGESO instruction?	NGESO will remain responsible for the overall restoration strategy and will direct DNOs, TOs and other parties to act consistent with that strategy. That may mean delaying the start of a DRZ process to a time that aligns with wider system restoration. The preference, as in current restoration plans, is that the National Grid Electricity System Operator (NGESO) instructs and coordinates, delegating responsibilities to others as appropriate. In the future, once the distribution restoration zone (DRZ) concept is established, where a plan does not have a time-limited output and does not require transmission network access to facilitate restoration, the distribution network operator (DNO) may independently start the restoration plan. On loss of communications to NGESO or on agreement with Scottish transmission network owners (TOs), the licence area TOs may assume responsibility for restoration following existing protocol.

Question	Response
Wider question, what would be the role of distribution system operators (DSOs) here and in the future going forward?	This organisational model was developed to align with 'World B' from the Energy Networks Association (ENA) Open Networks project, which is the current view of the most economic means to deliver DSO capability. Many aspects of what is being proposed in Distributed ReStart align with wider industry developments that can be grouped under the 'transition to DSO' heading. Distributed ReStart includes the need for enhanced monitoring and control of the distribution network and distributed energy resource (DER), more active intervention in network operation by the DNO/DSO control engineers, and new commercial relationships between the DNO/DSO and DER service providers.
In reality, how would all parties maintain the timely contacts and responses during restoration process? This simulator exercise obviously can show the live SLD for all parties, but when it comes to a real Black Start, would each party use the same software, or I suppose not?	Communication of status information, instructions and confirmation will be critical to a successful restoration process. Although each party may be using different tools to manage their own assets, there will have to be appropriate exchange of information between systems and people to support the process. NGESO will maintain a holistic view of restoration through visibility of transmission level joint restoration plans and Inter-Control Centre Communication Protocol (ICCP) connections between NGESO and DNOs allowing a view of the DRZ though linked Supervisory Control and Data Acquisition (SCADA) systems.
Impact of type of Black Start – LF relays?	In any DRZ, the DNO will have to decide on the priority order of switching demand, which may take account of a range of factors including the criticality of that demand and its impact on DRZ stability. This may also depend on the cause/mode of shutdown, i.e. a gradual exhaustion of active power may have resulted in many more low frequency (LF) relays operated than an immediate shutdown in which LF relays didn't have time to operate. Network preparation takes account of the requirement for protection changes equivalent to transmission level restoration.
Are all MW equal? Visibility of key demand (return supplies to hospitals, or chemical works for safety?)	Under a restoration, there are no priority loads, and the technically optimal restoration method should be used. Early restoration of supplies to distribution substations and their auxiliary supplies, even if end customers are not re-energised, will help to maintain operability of the network. However, the resilience of critical substations should be ensured by appropriate sizing of batteries, diesel backup or other means.
Number of circuit breaker operations per site pre energisation to auxiliary supplies?	Ahead of a restoration, optimal pre-energisation states should be defined with the goal of minimising onload switching actions. This will be specific to each restoration zone.
All distributed energy resources (DERs) energised, but at only one load bank – so still at risk to a single loss (of load bank)?	Being at risk to a single loss (of a load bank or the anchor generator, for example) will be unavoidable in the early stages of restoration, but the distribution restoration zone (DRZ) process can be designed to reduce or remove that risk where resources allow. The resources available, however, may be more limited than in conventional restoration planning, and the risk may have to be tolerated for longer.

Question	Response
What is the practical visibility of what is/isn't available/energised? National Grid Electricity System Operator (NGESO) video wall is known issue for restoration and other screens have been developed – what about distribution network operator (DNO)/transmission network owner (TO) control rooms?	Appropriate visibility of the process will be essential to all directly involved parties, particularly the DNO but also the DER. This will have to be designed in to the control room changes that each party makes to support implementation of a DRZ.
What is the goal of a DRZ? How does it fit into the local joint restoration plans (LJRPs)/overall NGESO strategy?	Circumstances, which may include restoring local demand, supporting re-energisation of the transmission system and restarting of larger power stations, or merely restoring substation and generator auxiliary supplies to maintain operability and thereby improve restoration speeds. NGESO will remain responsible for the overall national and regional strategies and will consider the role of DRZs within that. DRZs and LJRPs will be treated as separate power islands.
Have you considered resourcing for managing DRZs and LJRPs?	Implementing a DRZ will require additional resources, especially in the DNO. This forms part of the design and cost for Distributed ReStart and has been considered in the design stage report for OST, Chapter 10. Development of automation capability will mitigate an exponential increase in DNO management time if operating more than one procedure.
What about DNOs that run in parallel, like WISD6/WISD1/ACTL7, or the south London ring – CHSI/WIMB between UKPN(L)/UKPN(SE)? Does one party need to lead?	At this time, we are seeking to test and demonstrate the basic concept of a DRZ. While there are various locations where different DNOs are interconnected and the definition of a DRZ might be more complicated. We are currently focused on typical cases that cover the vast majority of the DNO networks. A range of combinations of current system configurations have been assessed, and some will require more complex plans than others.
Concerned about the true block loading and reactive capability of assets which were not designed with this in mind. Success means avoiding the edge of the specification sheet of these units. Block softening with autonomous batteries/load banks can be over-purchased at low cost, and would solve this.	We share the concern, and it is one of the main drivers behind our work on a distribution restoration zone controller (DRZ-C), which will supplement and support the control systems on individual distributed energy resources (DERs). However, the fundamental performance of the available generation resources will still be limited, and controllable batteries/load banks could be of great benefit. We note the point that 'over-purchasing' of low-cost resources could help to remove some of the risk.

9.2 Engineering Advisory Council

Table 48: Questions from the Engineering Advisory Council

Question	Response
In desktop exercises, you went through scenarios that would work. What about failure, was this tested and how does the process account for this?	We did not test failure within processes as control engineers were not yet familiar with the process; this is definitely a requirement for training, but the intent was to test the communication interfaces and the allocation of responsibilities. To mitigate the risk of control room system failure during the restoration process, manual back-up processes will need to be in place.
How would the simulator be developed further for training and stress-testing purposes? Have you considered adaptations that allow for these failure modes?	The project will make recommendations for training, share learnings from our simulation experience and propose options for adaptation of the method we used. Real training post-implementation needs to be individualised to the distribution network operators (DNOs) based on their own systems and specific restoration strategies. Desktop exercises will help to tease out the training requirements.
Your desktop exercises highlighted miscommunication/different understandings as an issue. What can be done to address this, and what implications does it have for scalability?	Control engineers require detailed authorisations and training which includes strategies to prevent miscommunication and a requirement to keep logs. The exercises are not reflective of this way of working due to lack of familiarity and our focus on drawing process improvement rather than training operators.
How might the process design vary for different regions, i.e. rural/ urban/different DNOs/load priorities (hospitals)? How is account taken of regional differences in areas such as human resourcing levels, operational practices and value of lost load?	The Electricity System Restoration Standard sets requirements on GB operators to deliver restoration within a set timeline; this now applies regionally. Needs are assessed nationally and regionally. Individual restoration plans will be specific to the combination of networks and energy resources available, but the command and control structure and process elements will remain common.
You talk about responsibility, but what about accountability? Will it require Grid Code changes and/or contractual obligations?	This is something the project team is addressing through the code modification proposals as part of its Procurement and Compliance workstream.
Have you considered an enhanced role for energy resources in the process? For example, the 'Resilience as a Service' project supported by funding from Ofgem's Network Innovation Competition seeks to use local renewable energy sources, battery energy storage systems and smart energy management to restore remote systems.	In our very early viability stage, we looked at a power island managed by distributed energy resources (DERs) directly but found that the changes required to give them visibility of network areas was unviable and that the systems, staff, training, etc would need to be completely new.
What about temporary generation such as back-up supplies for hospitals?	Our proposals focus on the ability to restore network areas in both regional and national restoration. This means we have focused on 33kV+ connected resources or those that are connected at 11kV and directly transform to a higher voltage. Smaller generators used as back-up or emergency supplies, e.g. in hospitals, may inform the restoration strategy and detailed plan for a given area, where demand that does not have any back-up may be prioritised for restoration. However, this will require detailed consideration, taking account of the criticality of different demands, such as hospitals.

Question	Response
What about community energy groups?	Our project focuses on 33kV+ connected resources or those that are connected at 11kV and directly transform to a higher voltage. This is due to our focus on national restoration; as more automation is introduced in the future, smaller resources may be able to participate.
Is it fair to say that more can go wrong in this more complex environment but that there is more flexibility to recover from issues arising during restoration?	We agree that this is a more complex process with more chance for individual failure. Individual components still need to meet a similar assurance standard, but the introduction of more energy resources leads to a higher chance that an individual component fails. Similarly, enhanced resilience is provided by the fact that a plan is not based upon only one resource, so there is resilience in the overall procedure by nature of more distributed capabilities. Automation (not present in conventional restoration) will look to mitigate some of this complexity. The requirements of the Electricity System Restoration Standard mean that, initially, we will need both distributed energy resources (DERs) and transmission-connected large generators but, over time, we expect to rely more on DERs for this service.
What consideration has been given to human factors (stress, fatigue, etc)?	This is an area the project needs to focus on/think more about. A well-developed functional specification for the distribution restoration zone controller (DRZ-C) is necessary as this should take much of the burden off the distribution network operator (DNO) control engineer but is not, in itself, sufficient.
Frequency management is a new capability for DNOs; is it reasonable to expect that the first time they might do this would be 'in anger'? DNO control engineers would need training and support to deal with extreme situations that could credibly arise – particularly as so few will ever have experienced a restoration event. Training alone may not be enough – do the distribution network operators (DNOs) need to gain experience first in frequency management under normal operating conditions?	Training will be critical, and we recognise this as a risk. Automation will partially mitigate the risks associated with this entirely new capability for DNOs, but manual procedures for fallback will be challenging for this reason.
What about trials of the automation processes?	We are taking a design/build through all the way to Hardware in Loop (HiL) testing at the National HVDC Centre using a prototype controller. We are not testing automation on the live power system through this project, but this is as far as it can be taken and includes use of real protection hardware, telemetry delays, cyber security protocols (and the latencies introduced) and failure of component sections including disaster recovery in the event of total failure or a cyber breach that requires recovery of the automation system itself. Each DNO will choose its own provider for a distribution restoration zone controller (DRZ-C) that meets the requirements of the functional specification, and they will undertake the required testing.
How will DNOs forecast demand? Can DNOs be expected to consider the variability of wind farm output? How firm is the anchor generation?	Our automation design focuses on preparation ahead of the event rather than judgement or forecasting systems on the day to deliver against this requirement. There will be a degree of control engineer judgement in terms of energisation of network areas with predictable versus more variable demand levels. Our automation proposal includes real-time assessment of the capability of connected resources to pick up demand and prevent energisation of an area where the maximum demand cold load pickup factor is greater than the block load pick up capability of the power island and flags this to a control engineer who can make a decision to override this and energise the demand.

Question	Response
It is assumed that DNOs will implement this automation. What are you doing to enable/address this?	We have engaged all GB DNOs through many different fora and have SP Energy Networks (SPEN) as project partners to ensure that DNO input is included at every stage. Specifically, we are engaging through regional development plans, Energy Networks Association working groups, desktop exercises (with control room engineers from every DNO) and direct DNO liaison. We plan to ramp up this DNO-specific engagement further as we move from 'final design' into implementation based on the wider restoration strategy timelines. HiL testing at the National HVDC Centre will provide further confidence to DNOs, but we will specify all designs as functional requirement to allow them to be tailored to individual DNO needs.
Having witnessed a desktop exercise, I was struck by the volume of communication. How many plans could be run concurrently? What determines how many plans are run concurrently? How does resourcing, stress, automation, adapt to an increased number of plans within distribution network operators (DNOs)? What assessment have you done on this?	If manual processes were to be adopted, we have assessed this and believe that one could be run at a time per DNO but with an exponential increase in required number of DNO control engineers as the numbers of distributed energy resources (DERs) in a plan or in a number of plans increases. With the introduction of automation, the focus is on approval and direction of transitional phases, meaning that a DNO control engineer takes on a supervisory role thereby increasing the opportunity for concurrent operation. Human resources limit our ability for concurrent operation on distribution level (and transmission level) procedures and is part of the instruction to start a plan process that NGESO remains responsible for.
Are we talking to system operators in other countries about what they are doing that is relevant to this?	We have discussed our approach within CIGRE and with our peers in Australia, US and Europe – but this project is a world first.
How will the planned live network trial be performed?	Part of the distribution network will be disconnected. We will then try to re-energise the islanded part of the network using the Distributed ReStart process and test it. We will not, however, try to synchronise it with the national transmission system.
When will Distributed ReStart be fully automated?	In theory, Distributed ReStart could be done manually, but we recognise that this would be very challenging. The functional specification of the distribution restoration zone controller (DRZ-C) is currently under development, and the first-generation tools will assist the DNO control engineers. Subsequent iterations of the DRZ-C will undoubtedly provide further support.

10 Appendix 2: Definitions and Acronyms

Table 49: Table of definitions

Delivery Criteria	Action
Active network management (ANM)	Active network management (ANM) connects separate components of an electricity network such as smaller energy generators and storage devices by implementing software to monitor and control the operation of these devices.
Advanced distribution management system (ADMS)	Advanced distribution management system (ADMS) is the software platform that supports the full suite of distribution management and optimisation.
Anchor generator	A generator with the ability to establish an independent voltage source (grid-forming capability).
Asynchronous communication	This is the transmission of data, generally without the use of an external clock signal, where data can be transmitted intermittently rather than in a steady stream.
Black Start	The procedure necessary for a recovery from a total shutdown or partial shutdown.
Bulk supply point (BSP)	A point of supply from a transmission system to a distribution system.
Cascading Style Sheets (CSS)	CSS is a computer language for laying out and structuring web pages.
Control telephony	The principal method by which a user's responsible engineer/operator and the company's control engineer(s) speak to one another for the purposes of control of the total system in both normal and emergency operating conditions.
Distributed energy resources (DERs)	DERs are electricity-producing resources or controllable loads that are connected to a local distribution system or to a host facility within the local distribution system.
Distributed energy resources management System (DERMS)	This is a platform which helps distribution system operators (DSOs) manage their grids with significant distributed energy resources (DERs).
Distribution management system (DMS)	DMS is a collection of power system applications designed to monitor and control the entire distribution network efficiently and reliably.
Distribution network operator (DNO)	A company licensed to distribute electricity in the UK.
Distribution restoration zone (DRZ)	Power island in the distribution network used for Black Start purposes.
Distribution restoration zone controller (DRZ-C)	A system that monitors and controls one or more DRZs.
Distribution restoration zone plan (DRZP)	A plan detailing the agreed method and procedure by which a distribution zone will be energised from start to end of a distribution zone.

Delivery Criteria	Action
Distribution system operator (DSO)	A future entity responsible for actively operating the distribution network. The Energy Networks Association (ENA) is currently investigating various DSO 'worlds' outlining the division of responsibility and which entity is most appropriate to fulfil this activity.
Electricity system operator (ESO)	A company with licence obligation to ensure effective balance of electricity supply and demand, to develop markets, advise on network investments and, in terms of Black Start, develop strategy and ensure that the electricity network is restored in cases of total or partial shutdown.
Emergency instruction	An instruction issued by National Grid in emergency circumstances as outlined in the balancing code.
Full time equivalent (FTE)	An employee's scheduled hours divided by the employer's hours for a full-time work week.
Grid supply point	This is traditionally the point where power is delivered from the transmission system to either a distribution network or a customer directly connected to the transmission system.
Hardware in Loop (HiL) testing	HiL testing is a technique that is used in the development and test of complex real-time embedded systems by adding the complexity of the plant under control to the test platform.
Heroku	This is a platform as a service (PaaS) that enables developers to build, run and operate applications entirely in the cloud.
House load	Operation which ensures that a power station can continue to supply its in-house load in the event of system faults resulting in power-generating modules being disconnected from the system and tripped onto their auxiliary supplies.
HyperText Markup Language (HTML)	HyperText Markup Language, or HTML, is the standard markup language for documents designed to be displayed in a web browser.
Independent distribution network operator (IDNO)	An independent distribution network operator (IDNO) is a company licensed by Ofgem to own and operate electricity networks.
Integrated energy management system (IEMS)	The IEMS or EMS system is a suite of applications for controlling and managing the power system.
Inter-Control Centre Communication Protocol (ICCP)	Also known as IEC 60870-6/TASE.2, this is a set of international standards specified by utility organisations to provide data exchange over Wide Area Networks (WANs) between utility control centres, utilities, power pools, regional control centres, and non-utility generators.
JavaScript	A programming language.
Latency	This refers to the delay that takes place during communication over a network.
Local joint restoration plan (LJRP)	A plan detailing the agreed method and procedure by which a Genset at a Black Start Station (possibly with other Gensets at that Black Start Station) will energise part of the total system and meet complementary blocks of local demand so as to form a power island. In Scotland, the plan may also cover more than one Black Start Station, include Gensets other than those at a Black Start Station and cover the creation of one or more power islands.

Delivery Criteria	Action
National Grid Electricity Transmission (NGET)	National Grid Electricity Transmission is the electricity transmission owner in England and Wales.
OpTel	National Grid Electricity Transmission operated power-resilient fibre-optic network.
Power island	A part of the electricity network that is electrically disconnected from the larger grid and operated in an islanded mode.
Python	High-level programming language.
Rate of Change of Frequency (RoCoF)	This is the time derivative of the power system frequency.
Revolutions per minute (RPM)	The rate at which the rotor is revolving, which is the number of times the rotor shaft completes a full rotation each minute.
SQLite	This is a C-language library that implements a small, fast, self-contained, high-reliability, full-featured, SQL database engine.
Scottish Hydro Electric Transmission Ltd (SHETL)	SHETL holds an electricity transmission licence in respect of the electricity transmission system in northern Scotland, which it owns and maintains.
SP Energy Networks (SPEN)	A Distribution and Transmission Network Operator and function to keep electricity flowing to homes and businesses throughout Central and Southern Scotland, North Wales, Merseyside, Cheshire and North Shropshire.
Supervisory Control and Data Acquisition (SCADA)	A computer system for gathering and analysing real-time data and used to remotely monitor and control equipment. Mostly used in telecommunication, utility, oil and gas industries.
Transmission network owner (TO)	A company licensed to transmit electricity in the UK.
Voice over IP communications	This is a method and group of technologies for the delivery of voice communications and multimedia sessions over Internet Protocol networks.
Web service gateway application	Applications that provide a single point of control, access and validation of web service request.

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