Distributed ReStart

Energy restoration for tomorrow

Closedown Report

October 2023

In partnership with:

tnei

SP Energy Networks

nationalgridESO

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1. Executive Summary

Black Start from Distributed Energy Resources (DER)

Following the completion of our third and final live trial at Redhouse in June 2023, the project has successfully met more than all its original and agreed objectives across all workstreams and support functions. This report will demonstrate and fully evidence that the Distributed Restart project has not only successfully delivered on all 10 of its objectives as defined and agreed in our Project Direction, but has also gone much further than originally scoped. This included the build and test of a Distribution Restoration Zone Controller (DRZC) prototype that allows for automation (with control room engineer direction) of the creation and stabilisation of a local power island.

The project delivered across all the main workstreams and has produced a number of key outputs as per the NIC bid requirements and our delivery criteria. These are fully described in detail in our *Final Findings and Proposals* report, and are summarised below:

Power Engineering and Trials (PET):

- defined the technical capabilities required to enable a feasible distribution restoration zone (DRZ) (Deliverables 4 and 5)
- the live trials at Galloway, Chapelcross and Redhouse demonstrated the use of different technology types to prove successful energisation (Deliverable 6)
- in partnership with the Organisational, Systems and Telecoms (OST) workstream, we defined, developed and factory-tested a prototype Distribution Restoration Zone Controller (DRZC).

Organisation, Systems and Telecommunications (OST):

- defined the communications requirements for this process including automation via a new DRZC (Deliverable 1)
- confirmed the new organisational design, roles, and responsibilities (Deliverable 2)
- demonstrated how the restoration process and joint action would work in practice between the electricity system operator (ESO), transmission owners (TOs), distribution network operators (DNOs), and distributed energy resources (DERs) via desktop exercises (Deliverable 3).

Procurement and Compliance (P&C):

- defined the approach and process to procure services from DER providers (Deliverable 7)
- this was demonstrated via our procurement test event (Deliverable 8)
- facilitated distribution restoration through ongoing industry code changes (Deliverable 9)
- creation of business as usual (BAU) procurement contracts.

Knowledge and Dissemination (K&D):

- quarterly Stakeholder Advisory Panel meetings
- extensive industry engagement including Utility Week Live, Energy Innovation Summit (was Low Carbon Network Innovation) and the Energy Networks Association (ENA)
- production of live trial reports
- email campaigns to our registered database which has grown to over 840 industry parties
- project webinars.

The project secured via Ofgem, a further extension to the project to 31 October 2023 to enable a third live trial at the Redhouse grid supply point (GSP). This involved using a battery energy storage system (BESS) with grid-forming technology to restart the network and use of the prototype DRZC to stabilise and maintain the power island within voltage and frequency limits.

The project has detailed numerous recommendations for industry, across all of our various reports, however, in this final *Closedown Report,* the project team highlight some key considerations we feel are important to take into account for future implementations of distribution restoration:

1. In the near term at least, distribution restoration zones will be implemented through the process of the ESO tendering for services and prompting a collaborative process of DNOs and DERs working through feasibility studies and design of potential solutions. Replication of the project outcomes will therefore be achieved through this collaboration with the ESO, who will be able to guide and support other parties in the required technical, organisational and commercial changes.

2. Our proposal for using RIIO-ED2 reopeners for DNO investment (DNO investment costs for the implementation of DRZs should be recovered through the price control mechanism and the reopener mechanism that Ofgem have provided in RIIO-ED2, available in June 2024).

3. Compliance with the new ESR standard – Section 12, Planned Implementation, highlights the work of the Electricity System Restoration Standard (ESRS), across the activities related to the GC0156 Code Changes and associated Working Groups. Whilst this project is still running, ESO has already started engagements with generators and DNOs in support of new tenders for restoration services, which now include scope for distribution connected resources. You can find out more by visiting Restoration Services on the ESO website.

4. Collaborative testing of processes with external stakeholders will be vital to develop ideas. Technical modifications to networks will vary dependent upon the specifics of the DNO area that will be used to form a DRZ. The outputs from the Distributed ReStart project provide information that can be used by DNOs and other stakeholders to inform their development and implementation of distribution restoration. Furthermore, ESO will lead collaboration with DNOs and DERs to guide and support other parties in implementing the required technical, organisational, and commercial changes.

5. Additional live trial demonstration – the most significant change of scope was the delivery of the additional live trial at Redhouse in June 2023. The trial successfully took the Distribution Restoration Zone Controller (DRZC) from a working prototype, (which was accomplished without any significant change in project structure or governance) to as close to a BAU implementation as possible. No actual customers were impacted, as use was made of isolated networks, protection settings and additional equipment, following extensive feasibility studies. As a result, the project was able to test both synchronous and non-synchronous devices' abilities to be used as anchor generators and top-up services.

6. Across our PET and OST reports, we have been able to produce functional specifications for both the DRZ Controller and a resilient and cyber-secure communications infrastructure for DNOs to use.

7. Time will tell if the implementation of distributed generation, planned for "go-live" in 2025 will significantly impact positively on restoration timeframes. However, as a project, we are confident that our designs, specifications and suggested solutions will have a positive outturn and benefit industry and consumers in the future.

Across this report, we have closely followed the Ofgem guidance from Appendix 2 of the *Electricity Network Innovation Competition (ENIC) Governance* document which prescribes the structure the report has to follow.

1.1 Background to the Project

The Distributed ReStart project is a partnership between National Grid Electricity System Operator (ESO), SP Energy Networks (SPEN) and TNEI (a specialist energy consultancy) that was initially awarded £10.3 million[1] of Electricity Network Innovation Competition (NIC) funding.

The project has explored 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). Current approaches rely on large power stations and interconnectors 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 electricity system restoration 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 that this project set out to address.

The project has tackled these challenges and has developed and demonstrated new approaches to restoration. Case studies on the Scottish Power Distribution (SPD) and Scottish Power Manweb (SPM) networks were 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. This has resulted in the current ESO tenders for restoration services, which commenced in June 2022 for service commencement around 2025, being open to offers from DERs.

1.2 Scope of the Project

Electricity system restoration (ESR) is the process of restoring the national electricity transmission system (NETS) following the highly unlikely, but highly impactful, event of a partial or total shutdown. National Grid Electricity System Operator (ESO) is responsible for ensuring there is an adequate provision for NETS restoration.

The current restoration strategy uses large power stations and interconnectors as electricity system restoration providers as shown in Figure 1. These providers must meet certain technical parameters, including the ability to start up without external power supplies. Once this occurs, the ESR provider energises sections of the transmission system, using local demand to establish a stable power island. Other generators then join this growing system to progressively restore demand across the country until full restoration is completed.

Currently there are four groups of organisations involved in restoration: National Grid Electricity System Operator (ESO), ESR providers, transmission owners (TOs), and distribution network operators (DNOs). Each organisation receives instructions and implements its part of restoration plans using a resilient and secure private telecommunications network.

What Black Start Looked Like Before Distributed ReStart

Figure 1: Restoration from a large generator

1 Ofgem provided £10.3 million of the project's total budget of £11.7 million, with the balance of £1.4 million contributed by the partners. Please refer to Section 10 for an update on the final project scope and funding position statement

However, the electricity system has been (and continues to be) transformed, driven by decarbonisation, decentralisation and digitalisation. In addition, the new requirements of the Electricity System Restoration Standard (ESRS) puts new obligations on ESO. However, through the frameworks, e.g. Grid Code, STC etc., ESO is able to place obligations on DNOs and TOs since ESO cannot meet the obligation alone, to ensure industry can deliver effective and rapid restoration.

ESR services needed to evolve in line with this and support the continued transition to a low carbon, decentralised future. This project had the aim of demonstrating how distributed energy resources (DERs) can contribute more fully to ESR. However, this requires a new and more complex approach to restoration. There were a number of technical, commercial, regulatory, and operational risks that needed to be worked through and mitigated before transition into business as usual (BAU), as highlighted in the original project perspective on innovation challenges as shown in Figure 2.

What the Future DER Restoration Could Look Like

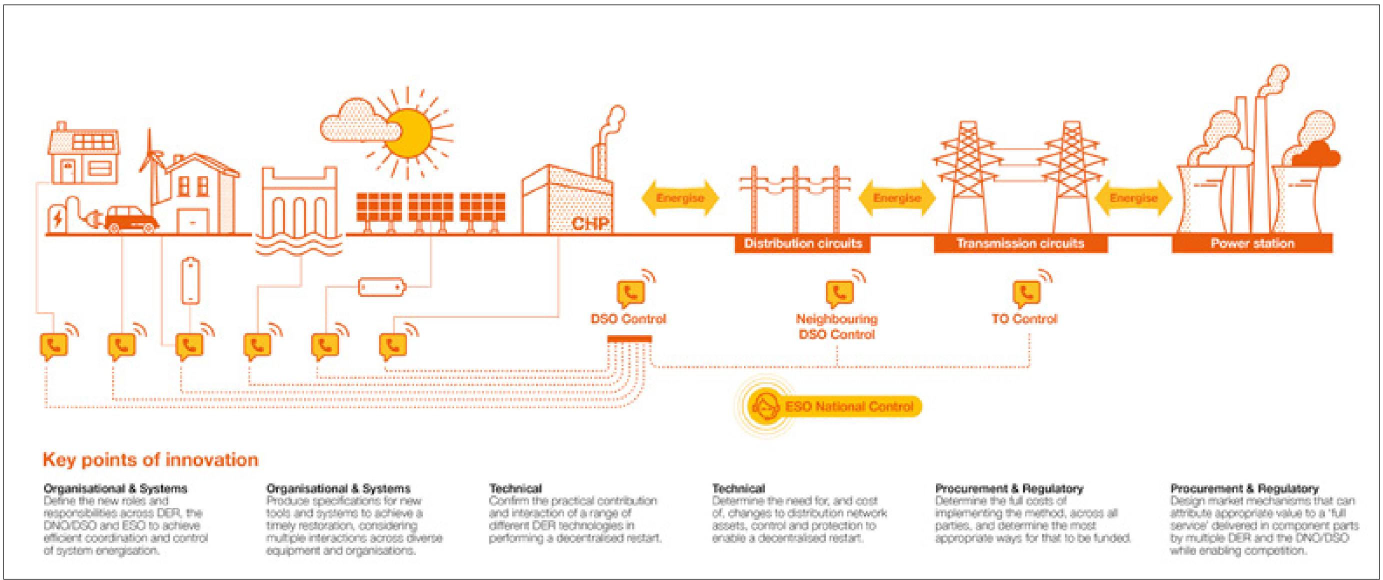

Figure 2: Original project view on restoration from DERs

ESR costs have risen steadily in recent years as the costs associated with keeping large generators on standby have risen. ESO will continue to procure ESR services as economically and efficiently as it can. Creating a collaborative and comprehensive solution between ESO and DNOs now, to allow DERs to participate in the new ESR market, will bring significant financial benefits to consumers through increased competition and lower costs and potentially achieve shorter restoration times.

1.3 Distributed Energy Resources (DERs)

There is an already large and growing pool of DERs who are currently unable to participate in the ESR market due to existing network restrictions, restoration methods and technical requirements for service providers. Figure 3 shows the current and projected installed capacity of DERs that could be considered dispatchable to some degree (so excludes wind and solar), currently around 12 GW, rising to 25 GW by the late 2030s and 35 GW by 2050. As can be seen, this future energy scenario (FES) by ESO, envisages battery storage and hydrogen providing approximately 90% of installed DER capacity by 2050. Batteries are prime candidates to offer restoration top-up services and the growth in batteries should boost the potential viability for DRZs. Adding intermittent sources like wind and solar increases the projected DER capacities even further and the project has shown that such sources can play an important role in restoration.

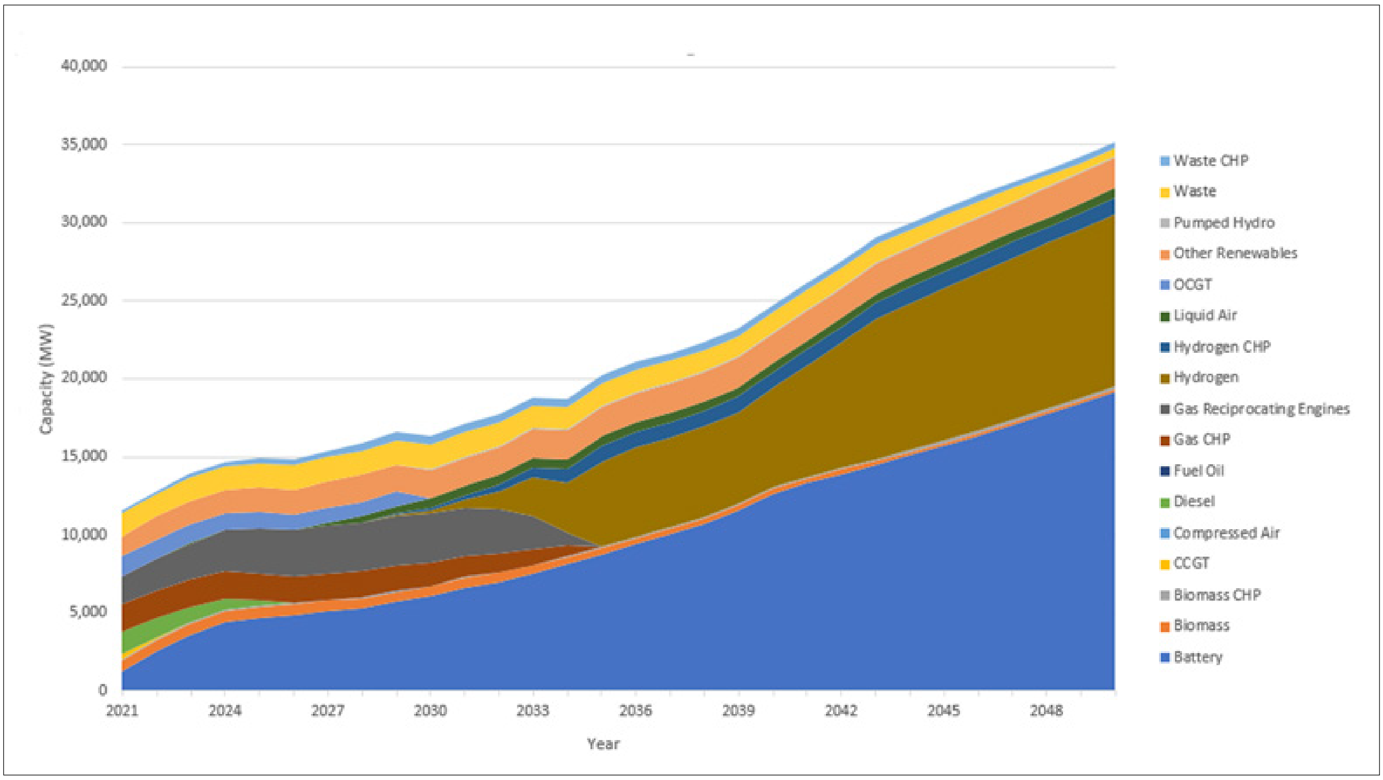

Figure 3: Current and projected installed capacity of DERs

Historically, a significant proportion of ESR provision has been from coal- or gas-fired generation, with some from pumped storage, hydro and biomass. ESO has also recently confirmed that combined services[2], interconnectors and sites with trip to house load[3] can provide services for ESR within the existing arrangements. Rising fuel and carbon costs, Government policies and the falling cost of alternative technologies have impacted the economics of large thermal generators, with several having closed.

1.4 Outcomes of the Project

1.4.1 Objectives Successfully Met

Following the completion of our second live trial at Chapelcross in July 2022, the project had successfully met all its original and agreed objectives, as listed in Table 11. In addition, we have gone further than originally scoped with the addition of the build and test of a Distribution Restoration Zone Controller (DRZC) prototype that allows for automation (with control room engineer direction) of the creation and stabilisation of a local power island.

We also secured a further extension to the project[4] to 31 October 2023 (with additional NIA funding, needed to replace a sufficient level of project contingency) to deliver a third live trial at the Redhouse Grid Supply Point (GSP). This involved use of a battery energy storage system (BESS) with grid-forming technology to restart the network and use of the prototype DRZC to stabilise and maintain the power island within voltage and frequency limits.

2 A combination of two providers is used for an electricity system restoration service

3 After loss of grid supply, a generator continues operating as a power island, maintaining supply on its own site, which may include loads associated with the power generation process and on-site industrial processes

4 Please refer to Section 7 for a copy of our Material Change Request

1.5 Project Structure

To derive the most benefits from the project, we organised the project around a central governance structure, comprising of five workstreams, a Project Management Office (PMO), resourced across the three partner organisations and including the Knowledge and Dissemination workstream, a Design Architect function, responsible for technical progress reporting and risk flagging, a Stakeholder Advisory Panel of industry and Government experts and, finally a Project Steering Committee, again, resourced across the three project partners with a senior ESO manager as sponsor.

The organogram below at Figure 4, gives a visual overview of the project structure. While there have been changes in the individuals assigned to the roles involved through the course of the project, this structure proved effective and remained unchanged. The Stakeholder Advisory Panel members are listed in full and reflect the final membership. All other names have been replaced by partner roles.

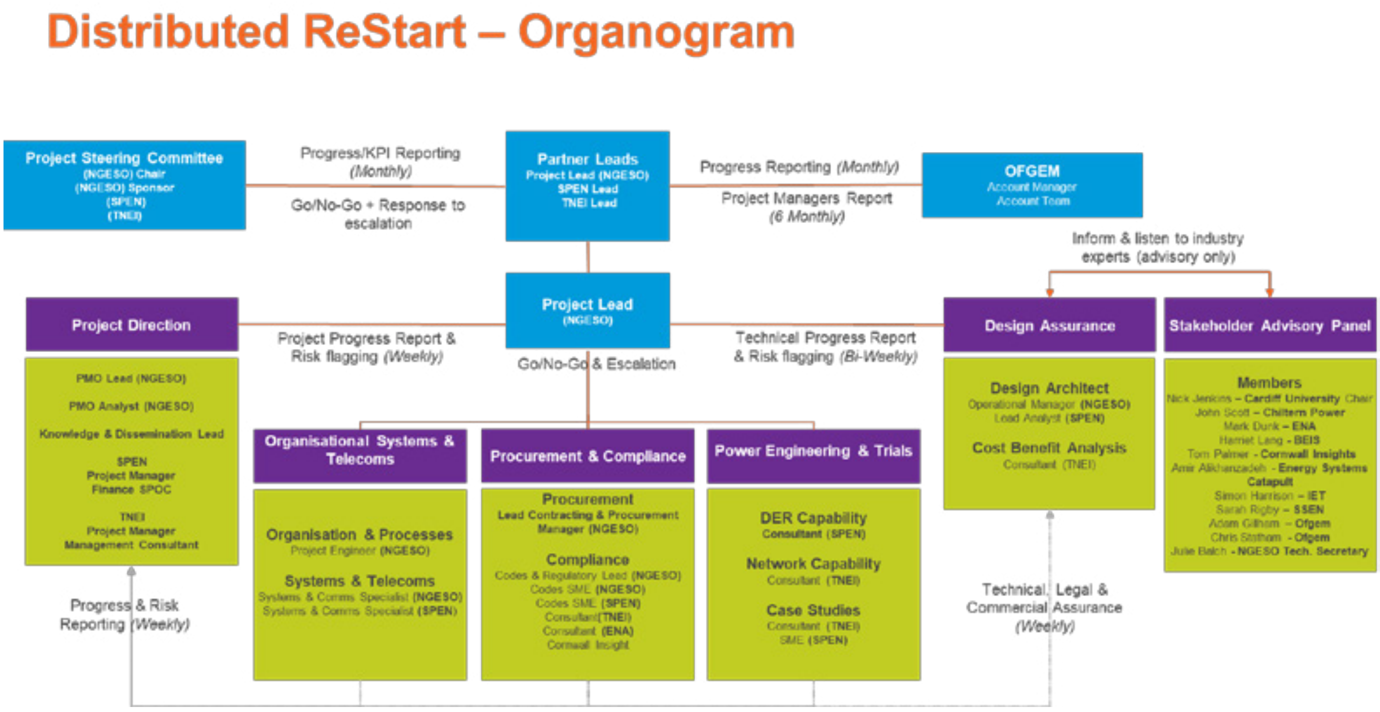

Figure 4: Project organisational structure

1.6 Project Direction Function

Project delivery is highly dependent upon ensuring alignment between all workstreams, maintaining a clear direction and a project management office to hold the team to account. The Project Direction function delivers against these goals.

1.6.1 Key Controls

The Project Direction workstream has established and maintained a consistent approach to project management through a cycle of project controls, including:

- monthly cost reporting from all partner companies contained in a centrally available system and detailed as far as possible against workstreams, cost categories and companies
- monthly finance surgeries to analyse costs incurred, verify their category allocation and review forecast costs

- monthly steering committee updates to senior leadership from all partner companies to scrutinise performance and action escalations
- weekly whole-project calls to address actions, update risks, update and mitigate any COVID-19 risks and promote awareness of whole-project outputs
- bi-weekly design architecture meetings to ensure alignment of all workstreams, supported by two senior engineers providing a design architect function
- weekly legal review of contracts to ensure value is being provided to the consumer through our significant works
- weekly PMO and workstream lead meetings to monitor risks, actions, planned leave and stakeholder engagement. This was considered adequate control to enable delivery and manage spend, progress, risks and issues.

1.6.2 Key Challenges

Contracting for live trials has proved to be very challenging. While contracts and non-disclosure agreements were quite quickly put in place, the supporting participation agreements (PAs) have proved to be the most challenging and time consuming to negotiate, agree and implement. To overcome these challenges, the project PMO Lead has held a series of operator specific virtual meetings, calling many parties and their legal teams together. This has resulted in a richer discussion, improved understanding of requirements and ultimately a more efficient process.

Participation agreements were in place in good time for the Galloway, Chapelcross and Redhouse live trials.

An overview of our legal work can be found in the table below.

Table 1: Legal work undertaken

Legal Document	Complete	In Progress
Non-Disclosure Agreement	19	0
Legal Contract	5	0
Participation Agreement	5	2

1.6.3 Plan and Progress

The project has successfully delivered against all design and delivery milestones to date. These include OST, PET and P&C workstream reports, as well as all project progress reports. In addition, to deliver against the DRZC scope and additional live trials has been extended three times, (to June 2022 for Galloway to complete, to December 2022 for Chapelcross to complete and to October 2023 for the additional Redhouse trial to complete).

1.6.4 Financial Performance

In successfully completing all our agreed deliverables (1–10), the overall project remains under budget while meeting all stage gate requirements. Budget outperformance was met through a leaner resourcing structure and effective utilisation of external resources. Extensive stakeholder engagement created project opportunities for low- or no-cost delivery of some required inputs. Overall project costs are strongly linked to live trials. These costs have been forecast for completing live trials at three locations compared with the bid document commitment to test at least two locations. Underspend to date has enabled the project to fully-fund the third live trial and the build and test of a prototype control system (DRZC). This is because of the careful management of our project finances. These two additional activities were not in the original scope of the NIC bid document, but are value-added activities which enhanced the learning output from this project.

As mentioned in Section 1.4.1, to allow for a contingency for the third live trial at Redhouse, the project secured additional funding via the NIA funding route, due to the post 2017 Ofgem rules governing additions to NIC-funded projects, such as this one.

1.6.5 Quality Assurance

The project has worked closely with our Stakeholder Advisory Panel (SAP) consisting of independent experts from across the electricity industry. This panel scrutinised the outputs of the project, providing independent quality assurance raising points for investigation in later outputs, such as challenging the project team to be more innovative, leading, amongst other things, to the inclusion of the third live trial proposed for Redhouse. In addition, the panel also provided an independent third-party review of our *Final Findings and Proposals for Electricity System Restoration from DERs* report as required by Ofgem Deliverable 10.

2. Key Learnings Generated by the Project

2.1 The Main Learning Derived from the Method

All the main learning derived from the project is detailed in the *Final Findings and Proposals for Electricity System Restoration from DERs* report, as required by Ofgem Deliverable 10. The paragraphs below summarise the key learning points from each workstream contained within that report.

The Organisational, Systems and Telecommunications (OST) workstream was responsible for developing the process design and communications and systems to coordinate all parties involved in restoration, and highlight the changes required across DERs, distribution network operators (DNOs), transmission owners (TOs) and ESO. In 2021, despite the unforeseen challenges of COVID-19, the project ran a series of desktop exercises that proved hugely valuable in testing our proposals and allowing a wide cross-section of the industry to participate and share in project learnings. We also summarise the work done on systems and communications with links to further information on the significant work done on control system design, cyber security and specifications for resilient telecommunications.

The Power Engineering and Trials (PET) workstream was concerned with the technical requirements to establish power islands on the distribution network, following a total or partial shutdown of Great Britain's electricity network. The project has defined the concept of a distribution restoration zone (DRZ), which may incorporate multiple DERs to provide services such as energising the distribution network, restoring customer demand and "bottom-up" energisation of the transmission network" As summarised in the *Final Findings and Proposals* report, the terms "anchor DER" and "top-up services" have been defined and described the capabilities required of DERs as well as identifying what DNOs may need to do to facilitate a DRZ.

The technical viability of restoration from DERs was established through extensive power system analysis of case study networks, industry engagement with DER developers and specialist consultants, development and testing of a DRZ Controller, and the planning and successful execution of several live trials. The *Final Findings and Proposals* report highlights the key learnings relating to DERs, networks and automation, and provides a point of entry to the more detailed information in our other project deliverables.

The Procurement and Compliance (P&C) workstream sought to find the best way to deliver the distribution restoration concept for customers. It explored the options and trade-offs between different competitive procurement solutions, applying a strategic process to develop fit-for-purpose commercial solutions that are open and transparent, stakeholder endorsed and designed end-to-end with customer interests in mind. Just as OST had desktop exercises and PET had live trials, the P&C workstream ran a test procurement event to test our proposals and provide an opportunity for detailed and in-depth stakeholder engagement. The *Final Findings and Proposals* report summarises the P&C final recommendations and service designs, including the high-level process for DNOs and DERs interested in providing new restoration services. We emphasise the importance of stakeholder engagement, noting the wide range of activities undertaken to ensure that our proposals offer the best solution.

The Knowledge and Dissemination workstream ensured stakeholders were considered and communicated with through all project activities and deliverables. In the *Final Findings and Proposals* report we list and provide links to all project reports that provide full details of our learnings and recommendations. Over the 3+ years of project delivery, there have been various industry initiatives and developments influencing the wider context for Distributed ReStart, which have been drawn into the project's thinking to inform project activities and shape outcomes:

- The new Electricity System Restoration Standard gives new impetus to the development of distribution restoration.
- Many aspects of distribution restoration align with other developments in the distribution system operator (DSO) transition.

- As well as project activities on live trials, there have been other successful demonstrations of new electricity system restoration capability, such as the use of grid-forming wind turbines at Dersalloch.
- Other projects, like Resilience as a Service (RaaS) and Synergy, will implement new control systems that can support restoration from DERs or related functionality.
- Grid Code Modification GC0137 has established requirements for grid-forming capability, aligned with the project goal of harnessing a wider range of resources.

The project finally closed after an extension that enabled the successful completion of the third live trial at Redhouse, which went beyond the original project remit by testing a grid-forming battery and a prototype DRZ Controller. Distribution restoration is already transitioning to business as usual (BAU) with industry discussions on the implementation of the new ESR Standard and code modifications, (i.e. GC0156), to recognise the DRZ concept, terminology, roles, and responsibilities, having commenced a year or two before the project completed.

ESO will continue to procure ESR services as economically and efficiently as possible. Creating a collaborative solution between ESO and DNOs to allow DERs to participate in the ESR market is expected to bring significant benefits to consumers through increased competition, lower costs, and potentially shorter restoration times. As per the original NIC Project Direction from Ofgem, based on the development and demonstration of new approaches in Distributed ReStart, ESO has included the option of services from DERs in the ESR tenders run in 2022, which aim for service commencement around 2025.

3. Details of Work Carried Out

3.1 Introduction

This section provides a summary of the work carried out for each of the methods that were implemented for Distributed Restart, as detailed below. Each sub-section provides an overview of that method and a description of the work that was carried out including studies, investigations, design and testing, leading to the successful live trials at Galloway, Chapelcross and Redhouse. The vast majority of this work was run under the PET workstream, with full support from the other workstreams. The overall requirements for distributed restoration from DERs involved a tremendous effort from all workstreams in order to develop the requirements in the *Final Findings and Proposals* report, enabling network and non-network licensees to be able to understand the methodology below and, more importantly, how to implement it in their own networks.

3.2 Methods Trialled and Methodology Employed

The method that we trialled in this innovation project was electricity system restoration from distributed energy resources (DERs). We decided to focus on DERs in the tens of MW range connected at 33 kV or 11 kV. Some larger generators connected at 132 kV already provide restoration services, while smaller DERs would need to be harnessed and coordinated in much greater numbers to have the required impact. We determined that typical network topologies at 33 kV would allow the establishment of power islands under a 132/33 kV grid supply point (GSP), or bulk supply point (BSP). However, the methods can be adapted and applied to different networks. Fundamentally, this involves:

1. **Restarting an electricity system** from a DER, or combination of DERs, from a full or partial blackout (without external power supply).

2. **Maintaining energisation** of the newly-created distribution power island of aggregated DER and blocks of demand.

3. **Expanding and synchronising** with other power islands, energising further generation, and establishing a skeleton transmission network.

Some DER technologies are currently capable of self-starting and thus providing ESR services. However, restoration is not just about the essential power system parameters (inertia, reactive power, block loading, etc.), but also about the overall initiation and coordination of restoration using smaller, more numerous and dispersed resources.

At the time of starting this project, the coordination of ESR from DERs had not been proven, so there were significant commercial, organisational, regulatory, and technical risks and unknowns. To overcome these, we adopted a comprehensive approach that was innovative, ground-breaking, open, and collaborative, to test possible solutions and to minimise cost and maximise value for consumers. We believed that, if this was implemented as BAU at the time of starting this project, it would have involved an iterative and piecemeal de-risking of individual opportunities, resulting in a less holistic solution and at greater cost to the consumer.

3.3 Power Engineering and Trials (PET)

The PET workstream was concerned with the technical requirements to deliver distributed restoration. This included defining the concept of a distribution restoration zone (DRZ), which may incorporate multiple DERs to provide services such as, energising the network, restoring customer demand and “bottom-up” energisation of the transmission network. The terms “anchor DER” and “top-up services” were defined in terms of the capabilities required of DERs as well as identifying what DNOs may need to do to facilitate a DRZ. Figure 5 gives an overview of the concept of a DRZ that was created by this project:

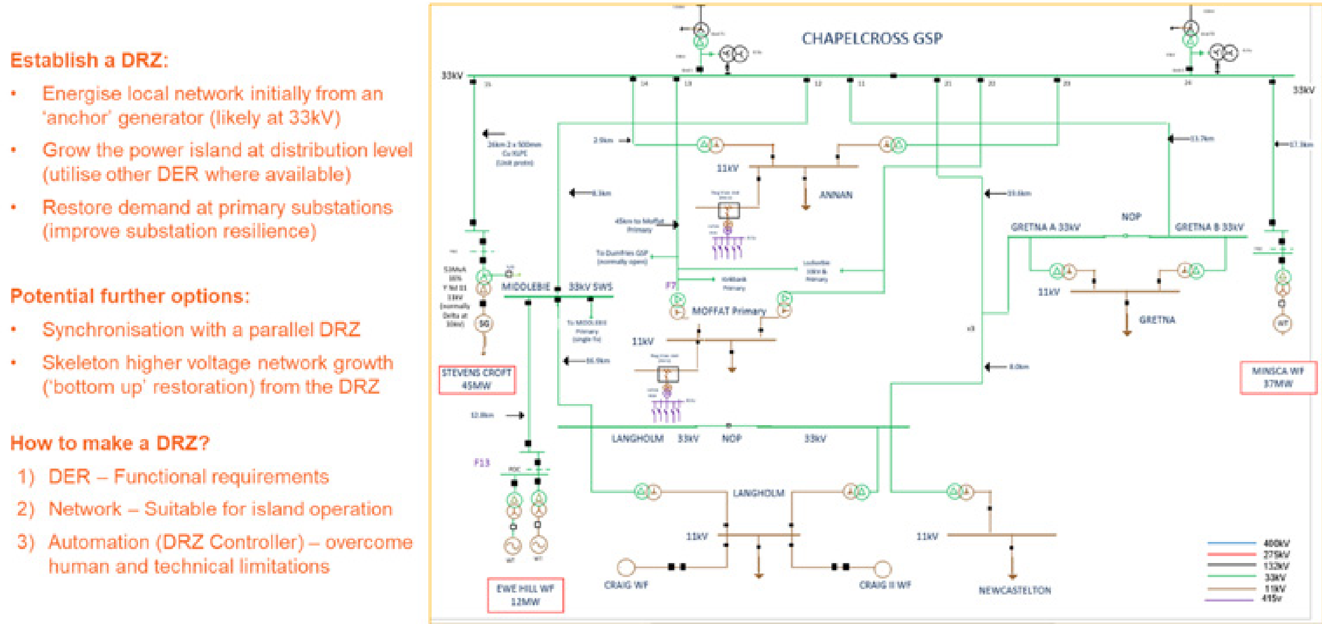

Figure 5: Distribution restoration zone (DRZ)

The technical viability of restoration from DERs was established through extensive power system analysis of case study networks, industry engagement with DER developers and specialist consultants, and development and testing of a DRZ Controller. The PET workstream also delivered the following live trial demonstrations of distributed energy resources being used to energise the network in a system restoration scenario:

- **Galloway Live Trial**

  Two distribution connected hydro generators, Glenlee (15 MVA) and Kendoon (13 MVA), have been used separately in live testing as the "anchor" generator (to initially energise the network and control the voltage and frequency). They generate at 11 kV on the system connected to the local 132 kV transmission network, which extends to the New Cumnock 275/132 kV wind farm collector substation, and to the distribution network at Glenluce 132/33 kV grid supply point (GSP), which incorporates approximately 100 MW of wind generation.

  Key testing goals for this trial were:

  → Develop strategies to energise the 132 kV transmission network (including grid transformers).

  → Energise the 33 kV distribution network, and primary (33/11 kV) transformers, and establish a power island with wind generation connected.

  → Test the viability of energising to the 275 kV network (via 275/132 kV 240 MVA super grid transformers).

- **Chapelcross Live Trial**

  This live trial utilised the Stevens Croft Biomass generator (45 MW) as the anchor. This is connected at 33 kV to Chapelcross 132/33 kV GSP distribution network, with the test network also including associated 132 kV overhead line circuits, a 46 MW wind farm, and a 400/132 kV 240 MVA super grid transformer (SGT) at Gretna.

  Key testing goals for this trial were:

  → Identify the ability of a steam generator to energise the distribution and transmission networks (including all relevant transformers) up to 400 kV.

  → Establish a power island with wind generation and demand (via a load bank) connected.

- **Redhouse Live Trial**

  This live trial utilised the 11.6 MVA Greenpsan battery energy storage system (BESS) as the anchor. This is connected at 33 kV to Redhouse132/33 kV GSP distribution network, with the test network also including associated 132 kV overhead line circuits, a 3 MVA solar farm, and a 33/132 kV 90 MVA grid transformer

  Key testing goals for this trial were:

  → Identify the ability of a non-synchronous inverter based generator to energise the distribution and transmission networks (including all relevant transformers) up to 132 kV.

  → Establish a BESS driven power island with solar generation and demand (via a load bank) connected.

  → Utilise the prototype DRZC to demonstrate automated start-up, optimisation and resynchronisation with the intact grid of the BESS driven power island.

  Furthermore, the PET workstream has delivered other vital work to support the development of future distribution restoration zones. These include:

- **Grid-Forming Converter (GFC) Assessments**

  As well as the power system analysis performed by the project team in TNEI and SPEN, the PET workstream also engaged external experts to investigate specific technical issues. This included detailed assessments of protection performance as part of planning for and de-risking the live trials. It also included collaboration with the University of Strathclyde and Iberdrola Innovation Middle East (IIME).

  In studies performed by Strathclyde, the ability to protect the Chapelcross live trial network was assessed based on the existing synchronous generator (SG) being replaced with an equivalent size (60 MVA) grid-forming converter (GFC) battery system. A key finding was that the 11 kV network (and lower voltages) may be adequately protected with existing protection settings, but more sensitive settings may be required for higher voltages, or alternative protections installed. Detailed analysis would be needed for each DRZ location.

  The IIME work investigated the use of GFC control in electricity system restoration applications, with experiments carried out in the state-of-the-art Dynamic Power Systems Laboratory (DPSL) at the University of Strathclyde, in conjunction with the Power Networks Demonstration Centre (PNDC). Simulations undertaken involved using a real time digital simulator (RTDS) model of the Chapelcross network and considered the ability of a GFC to energise the network from a blackout scenario by means of power hardware-in-the-loop (PHiL) testing. This paves the way for similar experiments in the future that allow for repetitive and non-destructive testing of GFC hardware through a hybrid environment that takes into account practical aspects such as communication delays and limitations existing in the real network, while allowing for testing electricity system restoration scenarios in different simulated network configurations and connections. The findings are described in the *Demonstration of Black Start from DERs (Live Trials Report) Part 2*.

- **Dersalloch Wind Farm – Virtual Synchronous Machine (VSM) Live Test**

  While this project was not delivered by Distributed ReStart and was supported separately by the Scottish Government via the Low Carbon Infrastructure Transition Programme, an agreement has been made by all parties that the learning is highly relevant to this project, and complementary to the findings identified under the Power Engineering and Trials workstream live trials report.

  Using an advanced “grid-forming” (GF) converter control scheme called virtual synchronous machine (VSM), a world-first electricity system restoration network trial from a wind farm was successfully completed during October 2020 by Scottish Power Renewables (SPR) and Siemens Gamesa Renewable Energy (SGRE) in partnership with SP Energy Networks.

  To achieve electricity system restoration capability, four individual turbine converters were equipped with the GF algorithm, and external 125 kVA diesel gensets were connected to provide supply to their auxiliary loads in order to self-start. The electricity system restoration GF procedure implemented a ramped approach to turbine energisation; this “soft start” ramping process softens inrush effects of network energisation and allows a reduced number of turbines to energise a relatively large network. The technique ramped the turbine terminal voltage from zero to 1 pu over a period of 14.25 seconds. From the trials completed at Dersalloch, several conclusions can be drawn on technical challenges encountered to enable electricity system restoration from a wind park.

The successful Dersalloch trials proved that it is possible to energise 132 and 275 kV transmission assets from a limited number of turbines within a grid-forming algorithm using a "soft start" ramping process to minimise network inrush effects. By including 1 MW of resistive load, the network saw an improved stability and dampening effect. Energisations were attempted with reduced voltage at both turbine terminal voltage and reduced tap settings on transmission grid transformers. This has the effect of reducing transformer inrush effects and reducing the risk of generator protection being activated by the disturbance causing the generator to trip off.

Using existing transmission protection functions it is not possible to provide any protection coverage on the network during the ramping sequence. By implementing a voltage-controlled overcurrent (VCOC) function within the network, protection coverage could be secured after 3.75 seconds with three wind turbine generators in service. Protection relays with VCOC functionality are widely available and already used in certain circumstances.

It has been demonstrated that using a traditional direct online energisation (DOL) it is possible to energise transmission networks up to 275 kV involving infrastructure rated at several times the wind park capacity. This learning is perhaps the most significant from all VSM trials completed and in essence proved that a ramping method may not be essential if restoration plans consider the availability of GF strength when assessing large transformer energisation.

3.4 Organisation, Systems and Telecommunications (OST)

This section describes the methodology employed by the OST workstream to meet the project objectives. The approach has been to consider:

- how the current electricity system restoration process works
- the key requirements for an electricity system restoration process
- the challenges of incorporating DER into the process
- what futureproofing is needed
- what options were available to fulfil these requirements.

To present a broad spectrum of options, the OST workstream reviewed both existing capabilities and the capabilities of technologies available in the near future. During this process, the workstream has actively sought challenge from stakeholders across the industry, including electricity system restoration participants, OFCOM, and the Energy Networks Strategic Telecommunications Group (ENSTG).

3.4.1 The Viability Stage

Between January and November 2019, OST was focused on the Viability Stage, as detailed in the initial report, titled *Organisational, Systems and Telecommunications – Viability Report – Nov 2019*, and was charged with highlighting (to our project stakeholders) the key challenges industry was facing at that time.

In this Viability Stage, a tremendous amount of work was done with the Energy Networks Association (ENA) to conduct a detailed analysis of the existing black start processes and procedures, as detailed in Chapter 7 of the viability stage report. Then, in order to future-proof our organisational analysis against the rapidly evolving DSO models, we defined four organisational models, in terms of the organisation driving and controlling the restoration process in a distribution power island, and the level of automation applied in implementing that process. This then enabled the design phase to refine these into recommended organisational structures.

In the design phase OST report, these models were further refined to develop recommendations on the process; the owners of each phase of restoration; the elements which require automation; and possible system solutions to achieve this. The workstream then went on to determine the basic viability of the method before effort was invested in detailed analysis or developing new processes. The Design Stage developed the options in preparation for testing. The planned industry consultation on the proposed design was achieved through the publication of the OST, PET and P&C Design Stage reports highlighted below, which were published towards the end of 2020. Industry was invited to review all reports published.

3.4.2 The Design Stage

The Design Stage, was detailed across two reports:

1. The *Organisational, Systems and Telecommunications Design Stage I* report delivered in October 2020, built on the conclusions and analysis from the Viability Stage to develop a preferred model for the organisational design and associated processes including an initial process design and detailed discussion of responsibilities across the stages of restoration. A requirement for a functional specification for operational telecommunications was also delivered, alongside potential costs of meeting the functional specification, a high-level end-to-end cyber security assessment, and an assessment of the requirements for information systems and the DER control interfaces required to facilitate Distributed ReStart.

2. The *Organisational, Systems and Telecommunications Design Stage II* report published in December that same year, analysed the latest (at that time) Government guidance for cyber security, and detailed the functional requirements for telecommunications, control systems and cyber security to ensure a fully functional, resilient, and robust Distributed ReStart service.

3.4.3 The Refine Stage

The final OST report, *Operating a Distribution Restoration Zone* published in September 2021, brought together all previous strands of the work undertaken by the workstream into the Refine Stage of the project, one of the highlights of which was the desktop exercises, which took place across the summer of 2021.

The desktop exercises 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 ESO) engineers.

Furthermore, we reached 21 different representative DER businesses and 8 different academic or other industry expert organisations. Figure 6 highlights the breadth and cover of the participants who took part in these important exercises, across the summer of 2021.

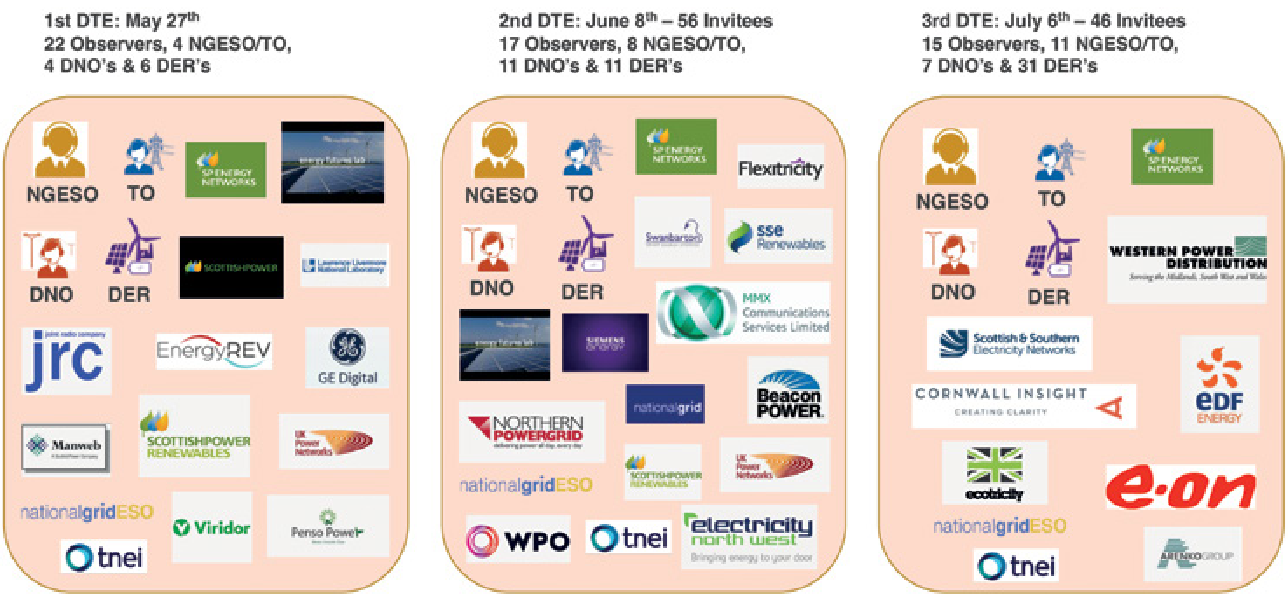

Figure 6: Desktop exercises – industry participants

All direct feedback and questions have been captured and responded to in the final OST report referenced above, and 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 0 MW 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 the BAU process needs 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.

Finally, post-delivery of desktop exercises, the project put the outputs of the procedural design, including identified improvements, up for challenge and review by ESO's Technology Advisory Council (TAC) 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 of the final OST report and the changes that were incorporated in response to TAC feedback are documented in Chapter 9 of the same report.

3.5 Procurement and Compliance (P&C)

Throughout the three years of developing the project's P&C designs, this workstream has used a strategy development process to provide a mechanism and rigour for the required commercial solutions, once all the inputs needed are available. The first P&C report – *Functional Requirements for Procurement & Compliance* goes into detail about the various stages explored for the development of our commercial designs. *A high-level outline of commercial and regulatory arrangements* was the second report that provides a high-level outline of possible commercial and regulatory arrangements through an iteration of the strategic process, as well as considering code change requirements in more detail.

In the Refine Stage of the project, it has been possible to propose firm options for the procurement and commercial structures. As a result, the final report – *Distribution Restoration future commercial structure and industry codes recommendations* was published on 20 December 2021. By including Appendix 2 *Draft Distribution Restoration Contracts,* we addressed Ofgem's deliverable 9 requirement found on the Distributed ReStart website in our Documents Library.

The strategy development process was iterated using inputs from the PET and OST workstreams, along with industry feedback. A set of commercial objectives for the service were agreed:

- Accelerated restoration times through a functional route to market for new service.
- Financial value to the end consumer through increased transparency, competition, and reduced barriers to entry.

These were used to inform the designs of proposed procurement approaches. Three procurement approaches were developed with approach two recommended to move forward for further development, following stakeholder feedback. Approach two enables contracting for each of the required services for a DRZ individually, as necessary, with the parties who provide the best value proposition. It provides the most flexibility for the procuring entity on the specific design of the service, and it also offers the lowest barriers to entry for potential providers. Table 2 shows an overview of these contractable services.

Table 2: Overview of the DRZ individually-contractable services

Service	Requirements	Description	Potential providers
Anchor generator (or power park)	Essential	Only one anchor generator is required per power island. Self-start and provide a controlled voltage source, able to energise the network to reach the next resource.	Synchronous generator, or other technology with required capability. A single point of connection is required with the DNO network.
Fast MW Control	Potential	May be required to supplement technical capability of anchor generator for example enhance block loading.	Battery, loadbank, flywheel, generator, others.
Inertia	Potential	Increase frequency stability of the DRZ and/or/ allow greater demand blocks to be picked up.	Synchronous generator, synchronous compensator (an inherent response is required without any measurement delays), others.
Frequency control	Potential	May be required to support the anchor generator to maintain frequency parameters during normal operation.	Synchronous generator, converter based sources with appropriate control, others.
Voltage control	Potential	May be required to enhance the MVAr capability of the DRZ to expand the island/energise to a higher voltage.	Wind farm, solar, battery, synchronous gen, Statcom, SVC, others.
Short circuit level	Potential	Increase the DRZ fault level. Facilitate protection operation at higher voltage levels or converter DER to connect	Synchronous generator, synchronous compensator, others.
Energy (MWh)	Potential	Enhance capability of the DRZ to restore demand above the capacity of the anchor generator. This could come from other any other gens on the island. (May be schedulable or intermittent.)	Schedulable MW – Synchronous generator (additional to the anchor), Intermittent resources (constrained and controlled by a set point), demand side management, others.

In 2021, the focus was on the development of the proposed end-to-end procurement process which indicates at a high level the roles for Ofgem, ESO, distribution network operators (DNOs), the lead procurement agent and distributed energy resources (DERs) service providers – both as anchor generator (AG) and top-up service (TUS) providers.
As part of this work, the P&C workstream has engaged with various stakeholders to review options and develop recommendations for:

- The lead procurement agent
- Contracting
- Settlement and funding.

As a result of extensive stakeholder engagement on the options above, the conclusions that we reached was that the ESO is best placed to lead the procurement process with collaboration from the respective distribution network owners (DNOs). To effectively contract with the DER providers, a tripartite contract between the service providers in a feasible distribution restoration zone plus the relevant DNO and ESO parties will be used. Finally for settlement of costs, all contractual costs for the DER providers will be recovered in the same way as ESO currently does for restoration services, which is through BSUoS. For any DNO investment costs, this should be recovered through their own price control for which Ofgem have provided in RIIO-ED2, a reopener mechanism available in June 2024. For more information to explain why this mechanism might work best, Chapter 9 Funding Arrangements in the final P&C report, *Distribution Restoration future commercial structure and industry codes recommendations*, elaborates on the various options explored.

Working closely with the other workstreams, the functional requirements for a distribution restoration service, and the "rules of play" to help govern the development of distribution restoration zones (DRZs), were also set up. To future-proof the distribution restoration service, the P&C workstream have coordinated the drafting of potential codes changes through a project code working group of code specialists across ESO, SPEN, TNEI, the Energy Networks Association (ENA) and Cornwall Insight.

Throughout the development of these specifications, the P&C workstream have actively engaged with various stakeholders ranging from a variety of DER providers, aggregators, BEIS, Ofgem and the DNOs via the Energy Networks Association (ENA) Open Networks project, to examine the options and agree the best solution to take forward.

This has been done through:

- P&C progress updates through the Distributed ReStart "The Live Trials Stage" podcast
- stakeholder webinars – one for updating DER providers on progress, and two more as part of the P&C Test Procurement Event
- a Test Procurement Event in mid-2021
- presenting at various industry forums including: ESO Incentives meeting with Ofgem, ENA's Commercial Operations Group, ENA's Flexibility Services workstream 1A and ESO's Whole Electricity System Joint Forum
- regular monthly meetings with Ofgem and BEIS through ESO Restoration team's tripartite sessions
- bi-lateral meetings with DER providers and DNOs
- regular checkpoint meetings with other teams developing similar DER-based services such as the Regional Development Programmes (RDPs), Power Potential, Resilience as a Service (RaaS)
- conferring on legal matters with contract experts and ESO's legal team, liaising with the ESO DSO team
- seeking advice on regulatory matters from RIIO price control leads within SPEN, ESO and Ofgem through various meetings.

3.6 Knowledge and Dissemination

Knowledge and Dissemination is a fundamental aspect of any innovation project. The ground-breaking learning from this project has been of great interest to a wide network of stakeholders in the energy sector, ranging from end consumers and DERs to academics, policy makers and network operators. The results of both simulations and real-world tests are of immense value to industry and will have a profound impact in maintaining efficient and economical ESR services in the medium- to long-term as the energy system decarbonises and decentralises. Our approach has also been of great interest to an international audience, with other countries facing similar challenges and opportunities.

Please refer to Section 13 Learning Dissemination for full details of this workstream's activities across the entire project lifespan.

4. Outcomes of the Project

4.1 Final Findings of the Distributed ReStart Project

The Distributed ReStart project has led to the development of clear and detailed information to allow other network operators and industry stakeholders to understand 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). To provide a central, focused point for accessing this information, the outcomes of the project are presented in our *Final Findings and Proposals for Electricity System Restoration from DERs* report, allowing interested parties now involved in the BAU rollout of contracting for distributed generation, to be able to understand how Distributed ReStart can be applied on their networks, and where detailed supporting information can be found.

Key points from the project's extensive library of findings are summarised below, allowing interested parties enough information to understand if a particular report is of interest:

- **DER Functional Requirements** – This lists the technical functional requirements which were developed within the project and are proposed for DER to provide the service of an anchor generator, or additional top-up services, within a DRZ. A fuller explanation of the anchor DER functional requirements is presented in Chapter 4 of the report by the PET workstream, *Assessment of power engineering aspects of Black Start from DER – Part 2*.
- **Network Requirements** – summarises the key technical issues which must be considered, and works that may have to be implemented, prior to a distribution network (and if applicable transmission network) forming part of a DRZ.
- **DRZC Generic Functional Requirements** – The Distributed ReStart project contracted several technology companies to propose the functional design of a DRZC system. These designs were reviewed to identify the functionality essential for a viable DRZC solution which are expected to be applicable in the wide range of conditions found across Great Britain. The requirements define the necessary functional capability of a DRZC but are technology/vendor agnostic and therefore do not dictate or recommend any aspect of how a DRZC should be implemented. The DRZ Functional Design Specification reports can be downloaded for DNO use from the *Documents Library* on the Distributed ReStart website.
- **The detailed functional requirements of the DRZC system** necessary for a business as usual (BAU) deployment (e.g. visualisation, communications monitoring/failsafe and system configuration/maintenance) are further detailed in Chapters 2 and 3 of the *Assessment of Power Engineering – Aspects of Black Start from DER Part 2* report. That same report also presents the designs proposed by the technology companies associated with the key functional requirements listed below (e.g. designs associated with "fast balancing" and "slow balancing").
- **Systems and Communications** – Integral to the restoration process is a power resilient, cyber secure operational telephony network. A specification for this system has been developed using the requirements from the organisational design, and the requirements from the DRZC design. The technical requirements to support the telecommunications networks include interfaces, protocols, bandwidth, latency, environmental concerns, and power requirements. The technology type and network configuration also play a crucial role in determining whether the technical requirements are met and options for this are included in the detailed telecommunications design requirements. Download the OST report, *Organisational, Systems and Telecommunications Design Stage II*, for full details.
- **Network Protection Studies** – Alongside the information presented in our *Final Findings and Proposals for Electricity System Restoration from DERs* report, Chapter 8 of the *Assessment of power engineering aspects of Black Start from DER – Part 1* provides a detailed protection assessment of a 11 kV to 400 kV case study network with the conclusions including a "rule of thumb" minimum fault level required at each voltage level for existing protections to be viable.

Chapter 7 of the *Assessment of Power Engineering Aspects of Black Start from DER – Part 2* report gives a specific protection assessment of the 11 kV and 400 V networks, and Chapter 8 of the *Demonstration of Black Start from DERs (Live Trials Report) Part 1* provides a protection assessment of the particular challenges when the anchor DER is a grid-forming battery energy storage system (BESS) – the converter cannot produce any fault current in excess of its full load current.

- **Live Trials and Restoration** – Along with system studies, the live testing has highlighted key issues, and potential mitigations, relevant to the restoration process:
  - → ***Islanded networks*** – Energising a network from a weak source (low short circuit level) is likely to result in significant harmonic and resonant frequency voltages and currents that are higher in magnitude and longer in duration than would occur on the same network when the fault level is much higher. A harmonic impedance study of the network to be energised can be undertaken to identify if there are resonances around typical inrush current frequencies, and therefore the potential for temporary over voltages (TOV).
  - → ***Transformer energisation*** – The transformer inrush currents, which can be of high magnitude and rich in harmonics, can excite the resonance of the circuit connecting to the anchor generator, resulting in temporary over voltages (TOV) that can last for several seconds. The TOV may operate the overvoltage protection at the generator terminals (typically set at approx. 1.1 pu to approx.1.3 pu with a few seconds' delay or instantaneous operation) resulting in the generator circuit breaker tripping on transformer energisation. The live trials demonstrated how energisation at lower voltages, the introduction of load (providing resistive damping), and the use of point-on-wave switching can all help mitigate risks associated with transformer energisation.

The *Final Findings and Proposals* report, also details next steps and the transition to business as usual (BAU), covering:

- **Commercial Considerations** – The outcomes and designs of the Procurement and Compliance (P&C) workstream will support the next round of Electricity System Restoration (ESR) tenders; the first of which is in the South East (SE) region and commenced in June 2022 with contract delivery from 2025 onwards.

  The Northern Region Tender launched in October 2022 with service delivery anticipated for Autumn 2025.

  It is intended that the two processes – the traditional process and the new distribution restoration process – will be combined to run in tandem. The process designs, draft contract and the test procurement documents that were developed in this project, will require further consultation by the NGESO System Restoration team to align with their tender plans. For both regional tenders, DNO collaboration will be a key requirement to the successful tender of DER providers to this market.

  Following the initial trial in the SE Tender, ESO will continue to evolve the ESR procurement process using provider and DNO feedback to ensure that it is fit for purpose for industry needs for distribution restoration.

- **Technical Considerations** – In the transition to BAU, it will be necessary for all DRZ participants to tackle the technical challenges identified in our project analysis and live trials. This will be driven by the process of ESO tendering for new restoration services and working with the DNOs and DERs to assess viability and define workable DRZs.

  DER owners will need to determine what service they are able to provide:
  - → Anchor DER – Each DRZ requires an "anchor" DER, a key requisite is having grid-forming capability.
  - → Top-up services – To supplement the technical capability of the anchor generator, stabilise or grow (connect more demand or network to) the DRZ, additional DER resources may be required. The requirements are defined in terms of "top-up services" (such as fast MW control, short circuit levels, reactive power, inertia) and in themselves are technology agnostic.

4.2 The Key Technical, Organisational & Commercial Issues

The key factors to be considered by DNOs when establishing areas of network as DRZs are below. The project has developed recommendations and guidance against each of these considerations. It is recognised that these may require investment on the network to implement a DRZ in a given area.

- 33 kV network earthing – existing earthing schemes must be evaluated to identify changes required to ensure safe operation, especially during initial start-up of the anchor generator and resynchronisation of the power island with the wider system.
- Network protection – existing protection functions and settings within the proposed DRZ must be reviewed to ensure safe operation throughout the restoration process, which may require the use of different settings during the early stages when fault levels are at their lowest. Many modern protection relays have group settings functionality that allows different settings to be used but the details of how this would be implemented in each DRZ would need to be assessed.
- Switchgear capability – studies should be performed to assess risks of transient recovery voltage (TRV) for fault and normal switching operations (together with the associated phenomena of reignitions for vacuum interrupter circuit breakers); the capacitive breaking capacity of switchgear should also be considered.
- To overcome the technical and human resource constraints associated with establishing and maintaining a DRZ, the recommendation is that the DNO should implement automation in the form of a DRZ Controller (DRZC). This would need to be developed by the DNO, but guidance/requirements/specifications etc. have been developed through the project, and that these are technology neutral so can be implemented using devices and systems applicable to the specific DNO in question.
- **Organisational Procedures** – From a people perspective, the resourcing requirements on distribution network operators (DNOs) are mitigated by the introduction of automation. It is expected that one DNO control engineer will be capable of managing a single distribution restoration zone (DRZ) when using the anchor generator to create a stable operating position and restoring supply. This automation will also support new frequency and voltage capabilities introduced through the organisational responsibilities.

  However, with familiarity and increased levels of experience and confidence in automation, a DNO control engineer may manage multiple islands in parallel, allowing stable operation to be maintained by the DRZC. This is not recommended for initial rollout but mitigates against an engineering resource 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 voltage and frequency control capability within DNOs under an emergency condition, it is essential that training focuses on this specific capability despite the support received through automation.
- **Restoration Processes and Procedures** – A key activity here is in establishing the processes required for individual DNOs or DERs to fulfil the enhanced roles and responsibilities necessary within the whole ESR process. This reaches from regional strategy development through to the organisation and coordination of a distribution restoration zone plan (DRZP). Distribution restoration is technically complicated – there is no “one size fits all” solution as all distribution restoration zones (DRZs) will be different. The costs for implementation are likely to vary widely across DRZs.

Finally, it is interesting to note that the new requirement on the DNO to manage voltage and frequency during the anchor DER stabilisation and subsequent power island growth stages represents a devolving of existing ESO/TO responsibilities, and this was widely discussed and commented on during the desktop exercises, with no overall objections raised by any party involved.

4.3 Cost-Benefit Analysis (CBA)

In early 2018, ESO published a *Product Roadmap for Restoration*, as part of its work on the future of balancing services. This set out the vision for the future of electricity system restoration:

> "… by the mid-2020s, we will be running a fully competitive electricity system restoration procurement process, providing there is sufficient competition to enable a market-based solution. This would include submissions from a wide range of technologies connected at different voltage levels on the network, with DNOs playing a more active role in the restoration approach."

This vision is reflected in both the medium- and long-term electricity system restoration (ESR) strategy. In the medium-term strategy, the focus was on "whether a tendered approach to procurement can be established". The timeframe for this was 1–3 years, which overlapped with the development phase of this project. To incorporate DERs, we needed to understand the service delivery requirements and options, the appropriate contractual structure, and how to deploy this solution. This project has clearly ensured the robustness of an ESR market in the longer term through enabling participation of new types of DER within the restoration process. This has helped to make the procurement of ESR services more open and transparent for customers and providers, which is another strategic goal of ESO.

Section 9 contains a detailed summary of the updated project CBA, using the latest Future Energy Scenario (FES) data for both transmission and distribution connected generation. The updates described in the CBA section have resulted in an updated calculated net present value of £130m.

4.4 Improvement in Network Performance and Technology Readiness Level (TRL)

The method developed and demonstrated in the project is expected to deliver improvements in network performance in terms of the time-to-restore (TTR) from a restoration event, and general robustness and flexibility of system restoration capabilities. This will be achieved by making available more diverse restoration options across all of Great Britain and helping the industry to meet the requirements of the ESR Standard.

The project focused on DER that had reached TRL 4-8 in the context of providing restoration services although, driven by stakeholder feedback and engagement with appropriate experts, we also investigated the use of other technologies. For example, our collaboration with the Iberdrola Innovation Middle East research team produced innovative work on grid-forming controllers. Ultimately, the case studies and live trials featured a broad mixture of resources, including synchronous and non-synchronous generation from both dispatchable and intermittent resources, and at Redhouse the planned testing of a grid forming battery and prototype DRZC.

Overall, we believe that the project has pushed the distributed restoration concept from TRL of 3-5 (depending on the specific DER technologies concerned) to a TRL of 8 with full-scale demonstrations in a working environment that has brought ESO, and the industry as a whole, to the position of being ready for commercial deployment.

Furthermore, in their evaluation in Appendix 2 of our project's *Final Findings and Proposals* report, our Stakeholder Advisory Panel noted that: "Currently we would assess Distributed ReStart to be at TRL (Technology Readiness Level) = 7, while commercial operation would normally commence at TRL = 8 or 9. We acknowledge that assessment of TRL level is not precise, but in view of the learning yet to come from the Redhouse trials we believe a current TRL of 7 expresses that a number of unknowns remain outstanding."

5. Performance Compared to Original Project Aims and Objectives

5.1 How the Project Helped Solve the Issue Described in its Full Submission

The bid submission document, *Black Start from Distributed Energy Resources*, stated: "The key problem to solve is how to pull the organisational coordination, the commercial and regulatory frameworks, and the power engineering solutions together to achieve electricity system restoration from DER. This project will develop and demonstrate ground-breaking new approaches to open the market to DER by designing and then testing technical, organisational, procurement and regulatory solutions".

In addressing the issue described above, the project has managed to create a viable means of restarting the GB network, using renewable DER for an innovative "bottom-up" approach. It did this by defining and testing solutions for the many challenges faced by the main actors involved in such a restoration event (DERs, DNOs, TOs and ESO) that allow the restoration to happen. Whether it involves network protection studies, regulatory and codes changes, organisational restructuring, resilient and cyber-secure systems and communications or new ways of procuring and contracting, the project has delivered solutions for all of these challenges.

As a team, we believe this was achieved via the way in which project resources (people, time and funding) were organised and structured, as can be shown in the organogram (figure 4) shown in section 1.5. This structure was found to work well in being able to manage the required Ofgem deliverables, plus, as an additional bonus, to be able to introduce additional, innovative project deliverables, such as the DRZ Controller build and test and the additional live trial for Redhouse

It is clear from the quality of the deliverables of each workstream, across commercial, regulatory, technical, organisational, systems, telecoms, and knowledge and dissemination, that this structure was suitable and able to deliver outstanding results that will benefit consumers and the industry for years to come.

5.2 How the Project Performed Relative to its Aims, Objectives, and Success Criteria

As a recap, the original aims, objectives, and success criteria defined at the bid submission stage, were asking the project to consider as many different types of DERs as feasible to demonstrate that the solution is applicable across technology types and across all of Great Britain.

Our project was focused on DER that have reached TRL 4-8 in the context of providing electricity system restoration services. The case studies identified for the resulting live trials, had a mixture of synchronous and non-synchronous generation types, from both dispatchable and intermittent resources, and this provided an opportunity to explore technology options.

This project was designed to deliver tested and proven concepts and frameworks that can now be implemented as BAU, assuming the specific implementation is technically and economically viable, and the outcomes of the project demonstrate that this has been achieved in a way that goes beyond the original aims and objectives.

It is clear from Table 11 in Section 13.1 that all required Ofgem deliverables have now been met and the project has delivered enhanced value and learning through the innovative development of the DRZC concept and the additional live trial at Redhouse delivered June 2023. The project has been very successful and has over-performed against the original criteria for success.

6. Modifications to the Planned Approach

The project delivery structure, as represented in Figure 4 in this report, was found to be effective and remained the same throughout, however, the initial planned approach of the two live trials at Galloway and Chapelcross was challenged by the Stakeholder Advisory Panel (SAP) as they believed that the project was capable of delivering additional learning. This led directly to some significant changes in both thinking outside the box and in our approach to solving the problem of black start from DER:

1. In the first half of 2020, the project engaged with several companies recognised as industry experts in the domain of power system automation and wide area control systems, to explore how a control system could automate key aspects of the restoration of a distribution power island. A competitive tender process led to the delivery of designs for a DRZ Controller by ZIV, SEL, SGS, and GE, which then informed our generic functional specification, detailed in the PET report *Assessment of Power Engineering – Aspects of Black Start from DER Part 2*. The original plan was to just specify a set of generic functional requirements for some sort of automation controller but, due to efficiencies in project delivery, we were able to make sufficient cost savings to allow us to progress with engaging a vendor to build a functioning prototype DRZC that we have tested in both a factory acceptance test (FAT) and independent hardware-in-the-loop (HiL) environment at the National HVDC Centre in Cumbernauld, Scotland. The functional design specifications for the controller, along with detailed specifications for the supporting cyber-secure systems and telecoms infrastructure are fully detailed in our PET and OST reports, released in 2020.

   These specifications can be used by DNOs to develop their own DRZC systems for application with their wider operational systems and using devices and communications systems that align to their existing BAU activities.

2. Following the above challenge to be more innovative by our SAP, it was decided to look at an additional case study in order to select a highly innovative third live trial at the Redhouse GSP, utilising the battery energy storage system (BESS) operated by Greenspan Energy. This trial, that took place in June 2023, goes beyond the requirements of Ofgem Deliverable 6 and was truly ground-breaking in its scope, involving utilising the BESS as an anchor generator with grid-forming technology to restart the network and use of the prototype DRZC and a solar farm acting as a top-up service (TUS) to stabilise and maintain the power island within voltage and frequency limits.

7. Significant Variance in Expected Costs

This Section has been redacted in this version of our *Closedown Report* and will be published to Ofgem only as a final finance report.

8. Business Case – Cost-Benefit Analysis (CBA)

8.1 Update to Cost Benefit Analysis

The 2018 funding submission to Ofgem for Distributed ReStart included a Cost Benefit Analysis (CBA). This appraised the potential benefits to the system and consumers of having access to restoration services from distributed energy resources.

The original 2018 CBA calculated a net present value (NPV) of up to £115m by 2050. A small update to this CBA, based on interim project learning, was then provided in the 2020 end of year report. This resulted in an increased NPV of £145m.

Here we provide a further update to the CBA which, compared to the original 2018 version, incorporates further project learning, updated data and assumptions, and some refinements of the overall modelling methodology.

8.2 Methodology

This CBA combined three sets of inputs:

- **Costs:** The cost of different types of generation technology providing restoration services. For simplicity, this was expressed as a £/MW/year cost. This included the core costs of the service, costs of technology retrofits (including retrofits on the distribution network), and costs associated with ensuring the readiness of thermal generation that would otherwise not generate in the energy market. We also considered (albeit in a simple way) the impact of concentrated market power on electricity system restoration costs.
- **Capacity:** the volume in MW of generation capacity, capable of providing restoration services, out to 2050 under various future energy scenarios. This was separated out by generation type, transmission versus distribution connected, and split into six different zones (to reflect the historic six electricity system restoration zones).
- **Requirement:** a requirement for restoration services in each zone. For simplicity, this was expressed as a MW level equivalent to the historic practice of procuring three providers within each restoration zone.

These updates were combined within the CBA model which determined, within each zone, what type of generation would be procured to provide the lowest cost restoration service. This methodology is summarised in Figure 7.

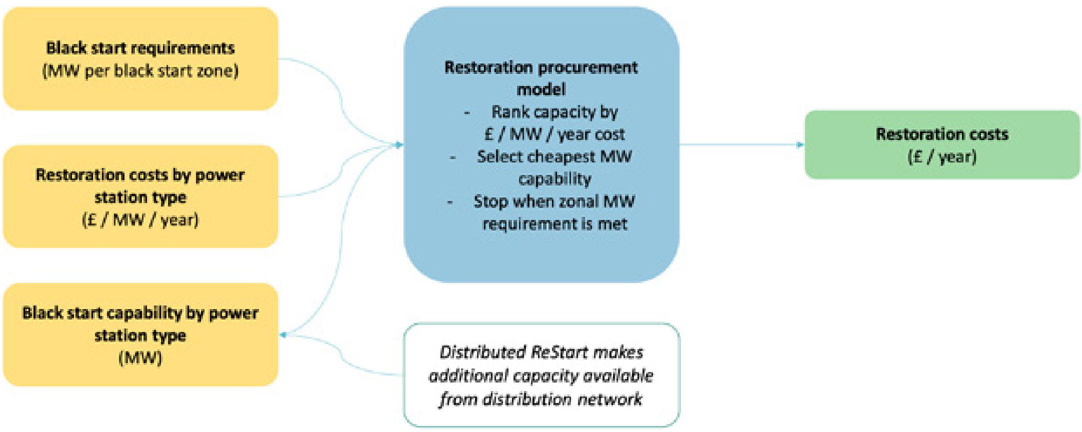

Figure 7: CBA model methodology

8.3 Changes in 2020 Update

8.3.1 CBA Methodology

The following changes were made to the CBA Methodology as part of the 2020 update:

- Data describing all four of the 2020 Future Energy Scenarios (FES) was incorporated into the model. The model was simplified to approximate the number of generators available in each zone, based on the capacity figures in the 2020 FES and assumptions about average generator sizes. This information is important when calculating the benefit associated with improving the liquidity of the market for electricity system restoration services.
- A different approach was taken to considering the de-rating of variable generation. In the original submission, variable generation was de-rated using typical load factors reflecting long-run average output. The 2020 CBA instead used load factors published for variable generation participating in the Capacity Market, which were not available when the original CBA was submitted. This reflected a more pessimistic case about the role of variable generation in providing restoration. This assumption has been revisited again in this iteration of the CBA (please refer to Appendix 5 for more information).
- The period over which retrofit costs for large transmission providers are recovered was shortened, from 10 years to 5–10 years. This reflected recent experience from ESO's restoration team about the nature of how these costs are currently being recovered contractually.
- A small error in the processing of DER costs was corrected.
- In addition, the year for discounting was changed from 2018 to 2020, reflecting a shorter wait until benefits start to be realised.

This update considered the sensitivity of the outputs to different FES scenarios but kept the Steady Progression scenario as the central scenario. This update also considered the sensitivity to variation in DER and DRZ retrofit costs. Please refer to Appendix 5 for a detailed description of all updates to the 2018 CBA assumptions.

8.3.2 Retrofit DER and DRZ Cost Assumptions

The cost assumptions included in the 2020 CBA update have been completely revisited based on experience from the live trials, and quotations received from service providers. A cost categories framework was developed to quantify and allocate the costs for the establishment, operation and maintenance of a distribution restoration zone (DRZ). A distinction has been made between one-off capital costs, ongoing annual costs, and long-term equipment rental costs.

Overall, we have found that the costs of distributed restoration are likely to be significantly greater than estimated during the 2018 submission.

8.3.3 DER Retrofit Cost Items

DERs would be responsible for ensuring their plant can support the restoration services required. In the case of anchor generators this may require investment into auxiliary generation to provide self-starting capability and a load bank to stabilise load during block loading operations. The size of auxiliary generation and load needed will be a factor of the anchor DER technology and size. For example, while a hydro station may require 0.1% auxiliary generation without the need for a load bank, a steam turbine generator would typically require auxiliary generation up to 20% of the DER rating, and load bank up to 10% of rated capacity.

Considering that restoration service contracts may only be 5-year contracts, it is envisaged that most anchor generators will elect to lease the necessary auxiliary generation and load bank capability, rather than outright purchasing to avoid the risk of these high-cost assets becoming stranded after the initial contract period.

Additional one-off costs applicable to anchor as well as top-up service DERs will include resilience works such as fuel stores, switchgear, surge arrestors, resistor-capacitor (RC) snubbers, new or modified protection and control systems (including point-on-wave switching controllers for anchor DERs), and telecommunications equipment for voice and data communications to the DNO control room. Modifications to the generator governor and/or automatic voltage controllers may also be required. Protection, frequency control and transient studies would need to be performed.

Ongoing annual costs for all DERs will include maintenance and annual testing of the plant's restoration capability, telecommunications operating costs, and the provision for 24-hour staffing or callout resources per DER installation. An overview of the cost items is provided in Table 3.

Table 3: DER retrofit costs

Type of Cost	Plant Costs	Systems and Communications	Human Resources
One-Off Cost	• Anchor DER: Switchgear, new protection and control including point on wave (PoW) • Generator control and self-start modifications • Surge arrestors and RC snubbers • Protection studies/modifications, transient studies • Resilience works, e.g. fuel stores	• Telecoms equipment	• Training of plant engineers
5-year Rental Cost	• Anchor DER: Auxiliary generator and stabilising load rental		
Operational Cost	• Annual testing and maintenance • Fuel costs	• Annual telecoms operating and maintenance costs	• Potential 24hr staffing/callout at anchor DER

8.3.4 DNO DRZ Cost Items

Anticipated DNO cost items are summarised in Table 4. The delivery of the DRZ Controller (DRZC) is envisaged to be the highest single-cost item, possibly costing more than £1 million per DRZ. A typical DRZ is likely to consist of five to six primary 33/11 kV substations. The DRZC will need to communicate to the RTUs and protection devices at each of these substations, hence the need for new protection IEDs, RTU and telecoms systems upgrades, as well as additional batteries for resilience (as distinct from larger scale load serving batteries). DNOs already have high data and telecoms security standards, and these will need to be applied to any new links between ESO, DNO and DER. At the anchor DER site, a 33 kV earthing transformer, circuit breaker and neutral earthing resistor, as well as a voltage transformer (VT) for synchronization checking will be required if not already available. Other one-off costs include implementing the required telecoms system upgrades; the creation of DRZ plans, roles, and processes together with associated training; and protection and earthing studies.

DNO investment costs for the implementation of DRZs should be recovered through the price control mechanism and the reopener mechanism that Ofgem have provided in RIIO-ED2, available in June 2024.

Ongoing operational costs include additional operational and control room staff to manage the DRZ system data points, training and assurance, and annual maintenance and testing of the DRZC system including the controller, telecoms, protection devices and all interfaces.

Table 4: DNO DRZ cost items

Type of Cost	Network	Systems and Communications	Human Resources
One-off Cost	• DRZ feasibility studies • Earthing and protection studies • 33 kV earthing transformer and circuit breaker at anchor DER substation • 33 kV VT for sync check • Neutral earthing resistor • New protection IEDs at 5-6 primary substations • Protection modifications at anchor DER substation • Batteries for telecoms resilience • Substation cabling and miscellaneous works	• DRZC system • Telecom's systems upgrade including resilience • RTU upgrades at primary substations for additional controls • Implementation into the control room including configuration and testing • Enhanced data and cyber security measures • Licenses for additional ICCP links to ESO control room	• Project staff • Equipment installers • Training for DNO staff on processes and systems, including DRZC • Engineering, analysis, protection and earthing studies etc.
Operational Cost	• Equipment maintenance and testing	• Maintenance of telecoms • Annual testing and maintenance of DRZC	• Additional operational and control room staff

8.3.5 ESO DRZ cost Items

The procurement of Distributed ReStart services is envisaged to be part of business-as-usual emergency system restoration services (ESRS), and hence no specific tender costs have been allocated. However, ESO would need to perform system-level feasibility studies to check that proposed anchor generation and top-services will yield a technically feasible DRZ. Other one-off costs include the installation of Inter-Control Centre Communications Protocol (ICCP) circuits to the DNO control rooms, the installation of additional data points on the EMS (energy management system), and the initial training of control engineer staff. Since the installation of ICCP circuits to the DNO control rooms have other benefits, only 50% of the cost is allocated to system restoration.

Ongoing procurement costs include annual payment for the availability of the service, which has been assumed as the same as current transmission connected costs. ICCP link rental, management of the DRZ plans, and ongoing change management and training of ESO as well as DNO staff are relatively minor costs compared to the availability costs.

Table 5: ESO DRZ cost items

Type of Cost	Procurement	Systems and Communications	Human Resources
One-off Cost	• DRZ system level feasibility studies	• ICCP link installation (50% allocation) and additional data points	• Training of control engineers
Operational Cost	• Availability payment	• ICCP circuit rental (50% allocation) • Management of DRZ plans	• Ongoing system change management and training of ESO and DNO staff

8.3.6 Transmission Operators (TOs) Cost Items

In most cases we expect DRZs to be implemented without any direct costs being imposed on the connecting TO. However, in some cases we expect, as noted in subsection 11.5, there may be a need for the DRZC to interface with transmission connected energy resources, particularly in Scotland where transmission is at 132 kV upwards.

8.3.7 Cost Reductions

We have assumed that the costs of distributed restoration will fall in the future as technologies mature. Our base assumption was that the costs will fall by 2% every year.

8.3.8 Costing Service Shortfalls

In some scenarios, it is possible that, without Distributed ReStart, there would be insufficient technical capability for providing restoration within a zone. In the first iteration of the CBA, such shortfalls were assumed to be addressed by "borrowing" restoration capacity from a neighbouring zone.

However, this is no longer considered to be a viable approach in the long term, due to the introduction of the Electricity System Restoration Standard, which requires that 60% of demand within each area is restored within 24 hours. This may limit the prospect of using restoration capacity "borrowed" from neighbouring zones, since all zones need to be restored equally quickly.

Please refer to Appendix 5 for our assumptions used in this analysis.

8.4 Results and Discussion

The updates described above have resulted in an updated calculated net present value of £130m. The change in NPV is summarised in the waterfall chart below.

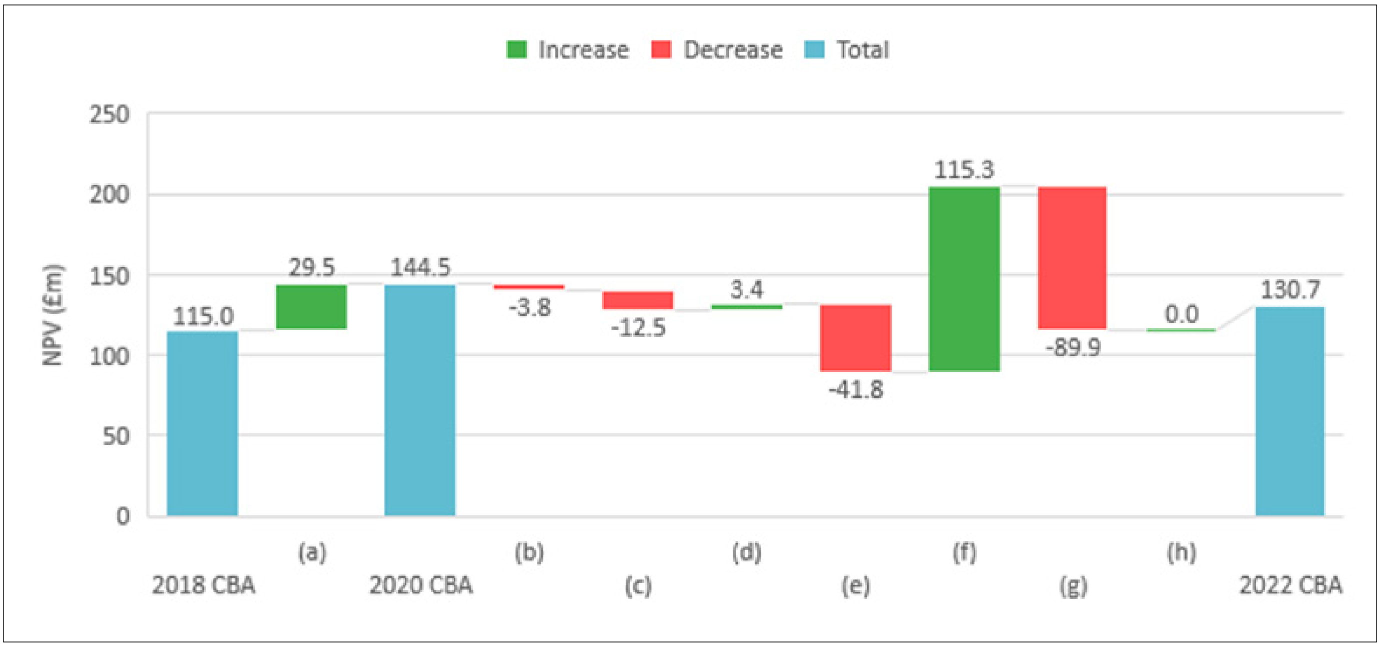

Figure 8: CBA update

a) These are the changes originally made in the 2020 update.

b) This captures small differences from some refinements in the spreadsheet model.

c) This captures the reduction in benefit arising from reverting to the original de-rating factors.

d) This increase in benefit is associated with the increase in the base service cost.

e) This arises from dynamically considering the costs of readiness.

f) Moving to the 2020 Leading the Way scenario in support of the net zero policy increases benefits significantly.

g) But, updating the costs leads to a significant reduction in benefit.

h) Discounting to 2022 increases benefits a little.

It is interesting to examine the mix of generation which the model selects for providing restoration under the Leading the Way scenario in 2050:

- 29% of restoration capability being provided by interconnectors
- 32% of restoration capability being provided by transmission connected storage
- 10% of restoration capability coming from dispatchable low-carbon power stations (e.g. carbon capture and storage)
- 24% of restoration capability being provided by variable generation on the transmission network (particularly offshore wind)
- 5% of restoration capability being provided by DERs.

DERs are being used relatively modestly – this is not surprising given the updated view of costs discussed above. However, this is in the context of a broader portfolio of restoration services which looks very different to historic practice. Under this scenario, only 10% of restoration services come from dispatchable power stations. Well over three quarters of restoration services are being provided by a mix of interconnectors, storage, and variable generation.

It is important to remember that DERs are present in both the method case, and the base case. However, the base case assumes that DER contribution to restoration happens more slowly and less efficiently. The benefit arises from this 5% of service being procured at a lower cost due to the application of learning from the Distributed ReStart project.

8.4.1 More Onerous Base Case

In a future where intermittent generation is not able to participate in restoration, the NPV of Distributed ReStart increases to £248.9m. In this case, DERs are providing 15% of restoration services in 2050, rather than 5%.

In addition, if DER participation in restoration is not permitted in the base case (i.e. we assume this would not have been delivered by the market on its own without an innovation project), then the NPV increases dramatically to £693m. This huge jump is because, in the absence of both DERs and variable generation, in the Base Case it is necessary to fund new generation capacity, purely for purpose of system restoration, with only ~86% of the restoration requirement being met by available generation capacity. The calculated project benefit of £693m could be an overestimate, however, as it is likely that the model may be unsuitable for considering such extreme cases.

However, this does reinforce an important message: restoration of net-zero energy systems could be very challenging without considerable innovation in new means of restoration. Distributed ReStart has been an important step towards giving the energy system access to new approaches of electricity system restoration.

9. Lessons Learnt for Future Innovation Projects

The lessons learnt were captured using a lessons learnt log that was circulated near the end of the project among the current and previous project team members. The task was facilitated by the Project Management Office (PMO) and the Project Lead. The categories covered are as follows:

- testing
- people
- organisation
- stakeholder engagement
- knowledge management
- leadership.

Outlined below in Table 6 is a summary of key lessons learnt.

Table 6: Key lessons learnt

Category	What went well in this project?	How would you improve the processes for next time, if applicable?
Roles and Responsibilities	The project team included a design architect function with members from both ESO and SPEN, with a responsibility to co-ordinate and ensure consistency of thinking and approach across all workstreams. This mitigated against a risk of inconsistency and divergence due to members being part of several organisations.	The design architect function provided additional support to the Project Lead and to each of the workstream leads to support the exchange of knowledge and provide direction. We recommend large and diverse projects with multiple partners follow this approach. They will benefit from having suitably qualified people assigned to a coordinating role, in support of the project leadership but separate to it.
Timelines/Order of Activities	The bid document was pulled together with the knowledge that was available at the time and with that the order and timelines of the required activities under the project workstreams were drawn up. As the project moved through the stages (Options, Design, Refine) further knowledge and understanding of the required activities became clear; for example, the P&C workstream needed outputs from the PET workstream to feed into their activities. This did not quite align with the timeline that was initially created and it would have been beneficial to re-evaluate and update the criteria in the bid document to reflect a change in the order of different activities.	Future innovation projects should build more flexibility in timelines and order of activities or provide an easier route for updating and changing how Ofgem will review the project meeting its success criteria. The P&C workstream delivered on its requirements and managed this in line with when the outputs from the PET workstream would be available. Three good quality reports and designs for the procurement process were delivered.

Testing	The team planned a mock tender event to test the functional criteria for anchor generator and top-up services with Distributed ReStart stakeholders around summer in 2021. The event was a success in that we managed to get five full bids across the two categories.	If repeating this activity, the team would run a separate consultation on mock tender documents to fix any issues on information clarity, detail level and general messaging. The team would then run a mock tender event with a longer timeline and open this up to the wider industry (not just project stakeholders) to receive data from as many different technology types as possible. The team therefore recommends that testing/trial efforts for P&C-type work are split into two distinct events.
Stakeholder Engagement	Various methods for communicating and engaging with stakeholders were used across the project enabling the team to adapt to changing circumstances such as COVID-19. This spanned both in person workshops and then more recently online events, podcasts, and workshops. Online events proved successful and cost effective and so continued through to the end of the project.	The project has maintained a high level of interest amongst industry stakeholders and has received significant input that has informed our designs. Future projects should seek to utilise the full range of communication and engagement options available to them, utilising online tools with supplementary resources.
Leadership	Despite many setbacks, the PET and Project Direction teams managed delays by extending the project twice to deliver three live trials at Galloway, Chapelcross and Redhouse.	It would be more effective if people were seconded to a project rather than a dedicated team as this leads to organisational churn and the potential for loss of consistent leadership or project expertise. By allowing the expertise available to work through problems, innovative and practical solutions can be found.
	Going out for multiple vendors at the scoping phase allowed: a) multiple vendors to continue to watch the project and be ready to develop these control solutions in rollout b) competition in the more complex and expensive demonstration phase tender c) the production of a vendor agnostic specification allowing for post roll-out tenders to have competition.	
Tender and Procurement	The aim was to create a single industry tender exercise by combining two parts to it, Lot 1 for the control system and Lot 2 for the cyber security and the communication.	Understanding competition law and doing things in a formal procurement tender process. Second lesson is to give yourself enough time to go through the process and to recruit a procurement consultant to make things easier.

Category	What did not go well in this project	How would you improve the processes for next time, if applicable?
Knowledge Management	A SharePoint site was used as the primary means of sharing project files and storing information. The SharePoint site has a clear structure at the highest level but through its use and management by multiple different people over an extended period it became more disorganised and content harder to find.	Knowledge management should be a consistent activity from the start of a large project. A knowledge management policy created at the start of the project, and someone being assigned responsibility for maintaining and managing the full range of content on the SharePoint site would have enabled it to be consistently managed throughout the project lifecycle.
Roles and Responsibilities	There were multiple changes in personnel during the course of the project, including project leadership. This added extra challenges as handovers were needed to ensure everyone was adequately briefed and the transition of team members ran smoothly.	Each organisation should ensure it provides the best support to the project, including appropriate management of workload for those split between the project and other responsibilities. Management of project information could be improved to support possible future handovers.
Legals	There were some significant delays in legal contracts being agreed and signed due to lack of expertise and legal representatives.	It is best to get legal representation at the start of the project to ease and expedite the process. PMO legal process tracker was created to track the progress and ensure all legal documents were up to date and signed. Use a professional consultancy to manage the legal process. Second learning point would be to start the negotiation around those trials and the tests very early as it can take a long time once those multiple negotiations going on with lots of different companies with lots of different spatial agreements on the go.

10. Project Replication

System restoration has always been a complex process and the distribution restoration concept developed and demonstrated in this project is more complex than conventional methods due to the greater number of parties involved and application of technologies not previously used in this way. The physical components and knowledge required to implement the method are detailed in our project deliverables, with our *Final Findings and Proposals for Electricity System Restoration from DERs* report providing a summary of and route into all project learning.

Changes in equipment and processes will be required on participating DERs and the distribution networks. However, in the near term at least, distribution restoration zones will be implemented through the process of ESO tendering for services and prompting a collaborative process of DNOs and DERs working through feasibility studies and design of potential solutions. Replication of the project outcomes will therefore be achieved through this collaboration with ESO, who will be able to guide and support other parties in the required technical, organisational and commercial changes.

As per the NIC governance, the intellectual property generated in the project has been shared openly in our project deliverables. Like other power system applications, implementation of a distribution restoration zone will rely upon intellectual property held by others, for example in the design and operation of specific DERs, the protection relays used on networks, or the telecoms networks essential to wide-area monitoring and control.

One of the important outcomes of the project is the proposed use of a Distribution Restoration Zone Controller (DRZC) to provide a degree of automation that would accelerate the restoration process, reduce the burden on DNO control engineers, and enable the use of a wider range of DERs. The project took an innovative approach to the design of a DRZC, engaging four separate solutions providers to produce their own designs and then deriving a generic set of functional requirements. The four individual designs are described in reports published on the project website, accessible to all. However, the generic requirements mean that DNOs are free to use whatever solutions provider they wish to choose and are not limited to those who have been directly involved in the project. We believe this approach has provided the best possible access to the intellectual property generated in the project.

11. Planned Implementation

11.1 BAU Electricity System Restoration Tenders

Whilst this project is still running, ESO has already started engagements with generators and DNOs in support of new tenders for restoration services, which now include scope for distribution connected resources drawing directly on learning gained from the Distributed ReStart project. ESO has a section on their website, Restoration Services, dedicated to these activities.

11.2 GC0156: Facilitating the Implementation of the Electricity System Restoration Standard

Following successful delivery of Grid Code GC0148 "Implementation of EU Emergency and Restoration Code Phase II" and the closure of all the associated working groups, Modification GC0156 has now been set up by the Assurance Team in ESO, to facilitate the implementation of the Electricity System Restoration Standard (ESRS).

This modification is required to clarify the requirements on Connection and Use of System Code (CUSC) parties, restoration service providers (RSPs) and distribution network operators (DNOs) taking part in restoration activities of their obligations so that National Grid ESO can satisfy the new ESO license obligation.

Please read *Workgroup Terms of Reference and Membership* for full details of the terms of reference.

11.3 Required Network Modifications

Following on from Section 10, this requirement is closely aligned with Project Replication and there are a number of initiatives ongoing, within the Grid Code GC0156 Modifications working groups that are "deep-diving" into the necessary modifications needed to be able to implement distributed restoration. For example, the remit of the ESRS "Future Networks Working Group" was to "discuss and identify system requirements needed to facilitate restoration based on the future generation mix and the required technical capabilities".

For details on the final outcome of the GC0156 consultation, please refer to the final *Electricity System Restoration Standard Implementation Consultation* report and, in particular, page 8 for the future network recommendations.

Technical modifications to networks will vary dependent upon the specifics of the DNO area that will be used to form a DRZ. The outputs from the Distributed ReStart project provide information that can be used by DNOs and other stakeholders to inform their development and implementation of distribution restoration. Further, ESO will lead collaboration with DNOs and DERs to guide and support other parties in implementing the required technical, organisational and commercial changes.

11.4 Actions Required by Network Licensees

Throughout the project, we have tried to engage with all impacted organisations, but in the final year focused on the DNOs as they are the most impacted by this new restoration process. Our approach was to build DNO awareness via a "restoration roadshow" where each DNO was targeted with a presentation, followed by an extensive Q&A session, covered by project subject matter experts. These sessions were recorded, and a consolidated version is now available on the Distributed ReStart website.

The sessions included the organisational change impact assessment and training needs analysis developed as recommendations from the Distributed ReStart project work, as shown in Table 7.

Table 7: Network Licensee 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 DRZ.
	Systems	No expected changes in England and Wales. For Scotland, elements of the control system may be installed at transmission level (132 kV).
	Telecommunications requirements	There may be a requirement for transmission Phasor measurement unit data to be exchanged with the DNO to enable synchronisation functionality.
	Training requirements	At least biennial training adapted for specific DRZ options.
	Staff requirements	No change required.
ESO	Interfaces	New interface with DNO.
	Systems	New ICCP for situational awareness of DRZC.
	Telecommunications requirements	Existing OPTEL is suitable.
	Training requirements	Training frequency is suitable, but content needs to include distribution options. Joint training with DNO, TO and providers is recommended biennially.
	Staff requirements	No change required.
DNO	Interfaces	The DNO now interfaces with ESO. The DNO now interfaces with DER (via DRZC and voice communication).
	Systems	New group telecontrol sequences added to ADMS. DRZC which meets the functional specification. New ICCP link with ESO
	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 DRZC system. 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 DRZP management. For this reason, where a DNO has multiple DRZP and Local Joint Restoration Plan (LJRP) options in their zone there may be a need for increased minimum resourcing or prioritisation based on staff constraints whilst further control engineers are called to site.

11.5 Actions Required by Non-Network Licensee Parties

As well as engaging extensively with generators at the distribution level via the ENA, the OST workstream desktop exercises and various technical workshops, we also engaged with several technology vendors during the invitation to tender process for designing a suitable DRZ Controller. Although GE Digital was eventually chosen to build and test the DRZ Controller prototype, three other suppliers submitted their unique designs, based on our functional specification and these are available on our web site via the links below:

DRZC Functional Design Specifications

GE Digital: *Distributed ReStart Deliverable 1 – DRZC Design and Testing Specification*

SEL Engineering Services: *Distributed Restart Zone Controller FEED*

Smarter Grid Solutions: *DRZC FUNCTIONAL DESIGN AND TESTING SPECIFICATION* (redacted)

ZIV: *A functional design & testing specification report for the DRZ controller*

Clearly, the call to action that we have emphasised very strongly to the DERs we have engaged with, also applies just as strongly to SEL, ZIV, GE Digital and SGS to continue considering how to engage with DNOs and DERs in discussions on how their specific DRZC specifications could be rolled out into DNOs active network management (ANM) and/or distributed energy resources management systems (DERMS) solutions.

Table 8 summaries the main actions required by distributed energy resources (DERs), supported by their chosen DRZC supplier, if they wish to participate in distributed restoration.

Table 8: Non-network licensee changes resulting from the Distributed ReStart process design

Organisation	Area Impacted	Changes Required
Distributed Energy Resources	**Interfaces**	A new interface providing redundant 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 DRZC 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 DER must demonstrate a robust training process for restoration capability or a resilient automated response to DRZC 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.

11.6 Technical Network Modifications

In addition to the above changes that would be required, we have published extensive technical details of network modifications that DNOs and DERs will need to make, to implement a successful distributed restoration service on their assets. Section 2.0 of our *Final Findings and Proposals* report gives a detailed overview of the key technical findings and recommendations that have been derived from the successful live trials at Galloway and Chapelcross, as well as extensive information from the various network studies. The key findings were touched upon in Section 3.2 of this report, but have been more fully summarised below:

In the transition to BAU, it will be necessary for all DRZ participant**s** to tackle the technical challenges identified in our project analysis and live trials. This will be driven by the process of ESO tendering for new restoration services and working with the DNOs and DERs to assess viability and define workable DRZs.

DER owners will need to determine what service they are able to provide:

- Anchor DER – Each DRZ requires an "anchor" DER, a key requisite is having grid-forming capability.
- Top-up services – To supplement the technical capability of the anchor generator, stabilise or grow (connect more demand or network to) the DRZ, additional DER resources may be required. The requirements are defined in terms of "top-up services" (such as fast MW control, short circuit levels, reactive power, inertia) and in themselves are technology agnostic.

The key technical issues to be considered by DNOs, which may require investment on the network to allow it to form part of a DRZ, include:

- 33 kV network earthing – Existing earthing schemes must be evaluated to identify changes required to ensure safe operation, especially during initial start-up of the anchor generator and resynchronisation of the power island with the wider system.
- Network protection – Existing protection functions and settings within the proposed DRZ must be reviewed to ensure safe operation throughout the restoration process, which may require the use of different settings during the early stages when fault levels are at their lowest. Many modern protection relays have group settings functionality that allows different settings to be used but the details of how this would be implemented in each DRZ would need to be assessed.
- Switchgear capability – Studies should be performed to assess risks of transient recovery voltage (TRV) for fault and normal switching operations (together with the associated phenomena of reignitions for vacuum interrupter circuit breakers); the capacitive breaking capacity of switchgear should also be considered. To overcome the technical and human resource constraints associated with establishing and maintaining a DRZ, the DNO may have to implement automation in the form of a DRZ Controller (DRZC). This will primarily be required if either of the following "top-up services" are required:
  - → Fast MW control – This enables the block load pickup (BLPU) capability of the anchor DER to be enhanced (its ability to pick up instantaneous blocks of demand) to make a viable restoration strategy (e.g. pick up primary [33/11 kV] substations in a single step). The DRZC is truly innovative in requiring sub-second control of DER to achieve this (to maintain acceptable frequency levels). This DRZC function is called fast balancing.
  - → Energy MWhs are required to enhance the capacity of the anchor DER to restore demand. The DRZC will control the additional DER to ensure the generation/load balance is such that the frequency is kept within limits. This DRZC function is called slow balancing.

The live trials have provided learning that will inform the transition to BAU, highlighting key issues like:

- the level of transient voltages and currents in an islanded network
- transformer energisation and techniques to mitigate associated generator tripping
- switchgear and network reactive loading capability
- the accuracy of system modelling
- the benefits of live assurance testing.

As an example of cross workstream collaboration in the project and the wider BAU community, in Section 2.3.1 of the *Final Findings and Proposals* report, the anchor generator functional requirements have been incorporated into the new ESR contracts currently being used for the Feasibility 1 and 2 studies required for the South East regional tender and will be used for the follow-on stages for the Northern tender. Similarly, section 2.4.1 of that report summarises the key technical issues which must be considered, and works that may have to be implemented, prior to a distribution network (and if applicable transmission network) forming part of a distribution restoration zone (DRZ).

Section 2.5 of that report then explores the role of the automation function we envisage as being a key requirement in establishing and maintaining a stable power island or DRZ. Given the technical and operational challenges associated with establishing, growing, and maintaining a DRZ, and the limited human resources which may be available at the time of an electricity system restoration, it is anticipated that some level of automation will be required. The application of automation to the DRZ restoration process is further discussed in Chapter 3.4 of the PET workstream's *Report on the Viability of Restoration from DERs*, and Chapter 11 of the report, *Demonstration of Black Start from DERs (Live Trials Report) Part 1*.

11.7 Third Live Trial at Redhouse GSP

The wide area control system that has been developed within the Distributed ReStart project (up to the prototype stage) is referred to as a Distribution Restoration Zone Controller (DRZC). While neither of the first two live trials went as far as utilising the above automation of a DRZ using the DRZ Controller, the additional live trial at Redhouse, completed in June 2023, implemented and demonstrated the full automation functionality of the DRZC, in stages as follows:

- Phase 1 – Proving grid-forming capability of distributed battery energy storage system (on third-party network only).

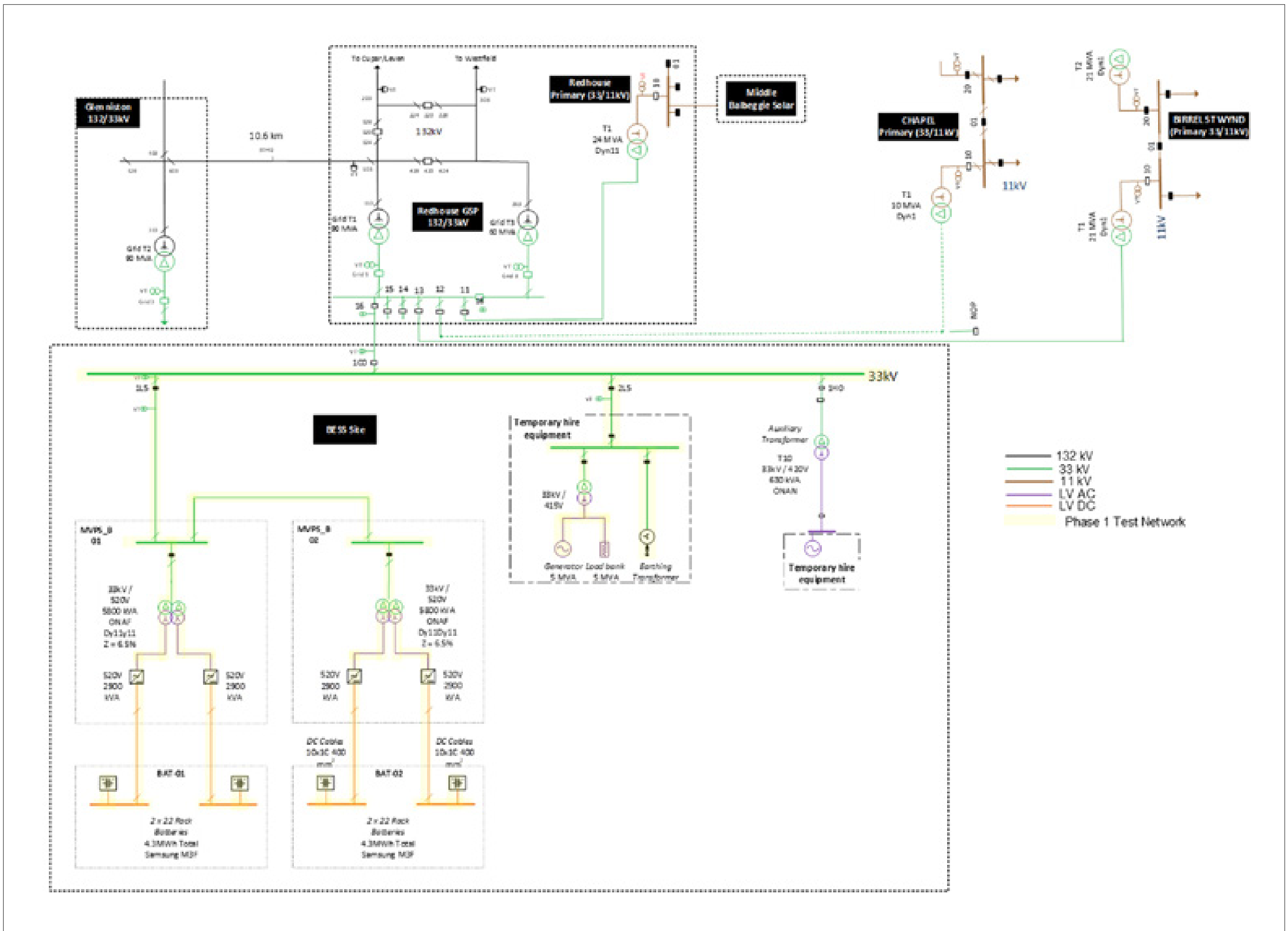

Figure 9: Phase 1 energising Greenspan 33 KV network

- Phase 2 – Proving grid-forming capability of BESS and ability to energise both 33 kV and 132 kV transformers/network.

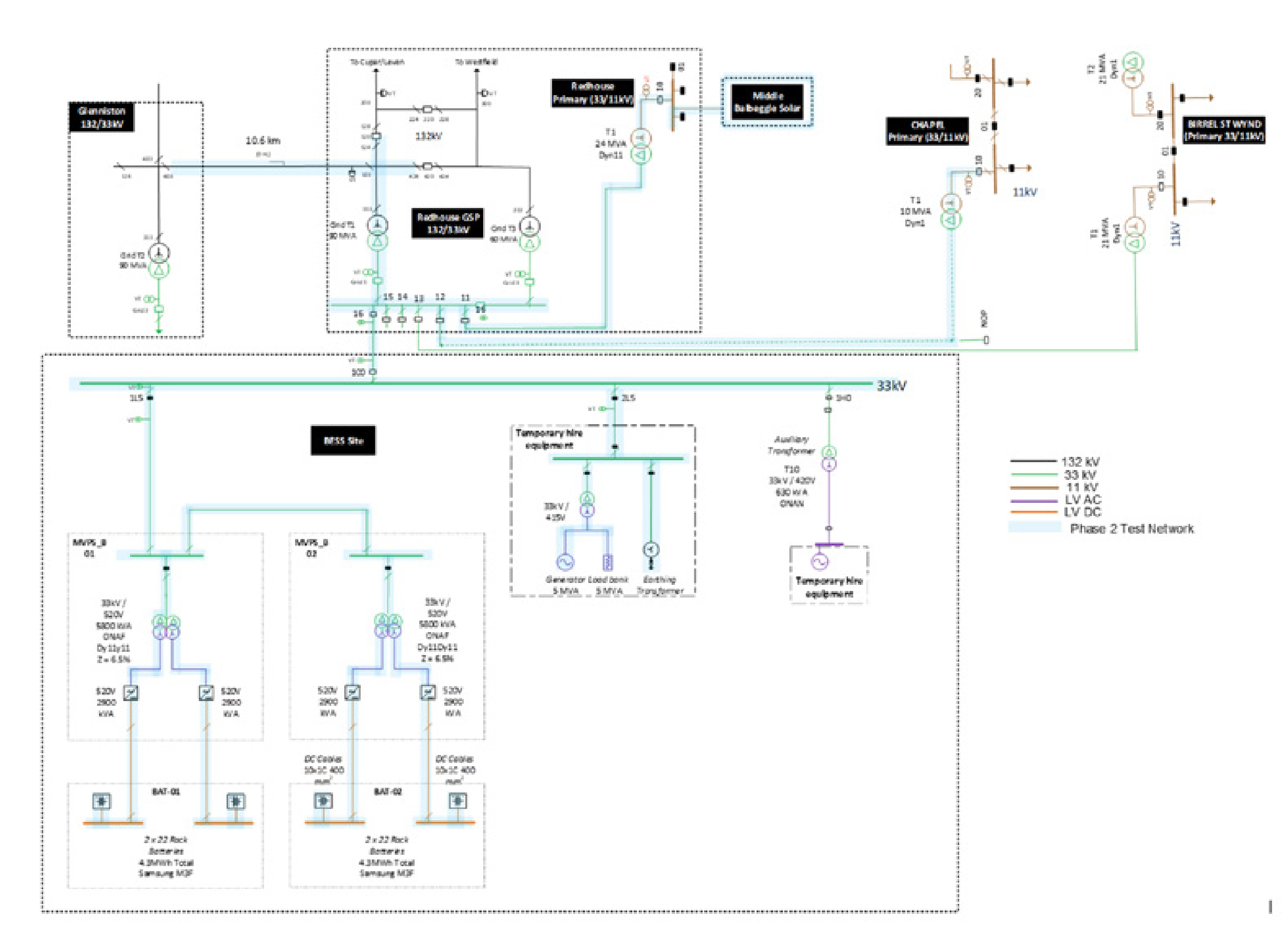

Figure 10: Energising SPD 33 kV network and SPT 132 kV network

Additional Goals (Phase 3)

Include a solar farm within tests to demonstrate ability of multiple DERs to contribute to islanded grid.

Implement DRZC control of island to demonstrate ability to simply respond to disturbances or have complete control of island.

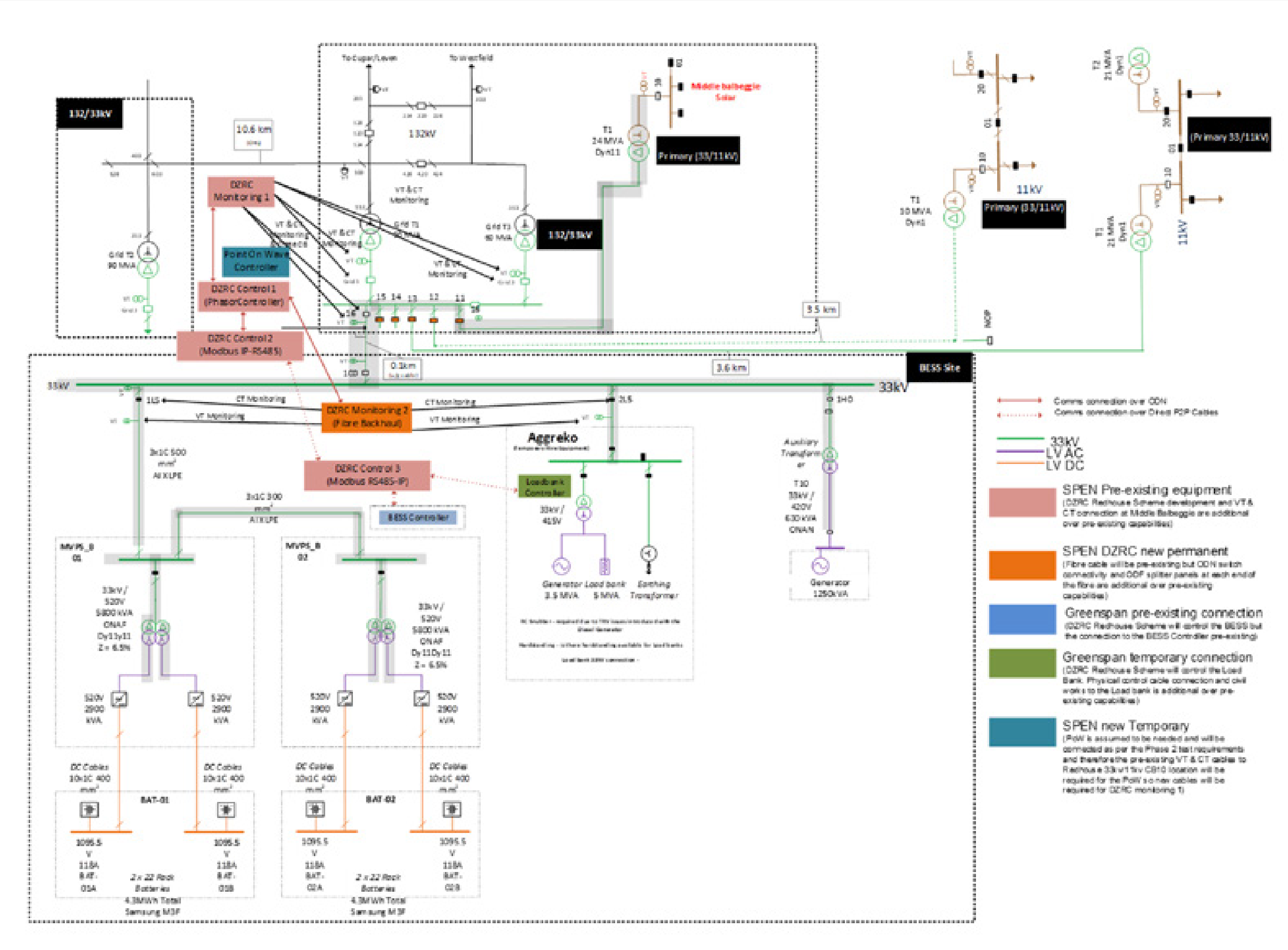

Figure 11: Phase 2 expanded/repeated under DRZC with loadbank control

The above phases are broadly the same as the previous plan discussed in the December 2021 PET report, *Demonstration of Black Start from DERs (Live Trials Report) Part 1*, and in most of our project communications until now. However, in consultation with Ofgem, our ESO leadership and project partners (as well as our Stakeholder Advisory Panel) we all felt that a demonstration of this type of battery technology's ability to restart the local network and energise up to supergrid level (132/400 kV) has been of great benefit to industry and consumers alike. The success of the factory acceptance testing (FAT) and subsequent *DRZC Factory Acceptance Testing 1* report by GE Digital in April 2022, gave us confidence to add the Distribution Restoration Zone Controller (DRZC) functionality, to provide a demonstration of the automation capabilities of our functional specifications in an operational live environment. The trial was run in accordance with good governance safety procedures and no actual customers connected to the Redhouse GSP were impacted as a result. Use was made of an isolated section of the distribution network to conduct the trials.

11.8 Anticipated BAU Costs for Industry

We do not have detailed anticipated costs for participants taking part in the procurement tenders for distributed generation (anchor generator, top-up services, or a combination of both) due to the complexity and wide-ranging types of DNO networks, and the varying levels of maturity and readiness to be able to design, procure, implement, and test the specific configuration of equipment and new network services needed to support a DRZ Controller and associated DRZ plan. Each implementation will be unique and will happen at different speeds and across many geographical zones. In table 4, Section 8.3.4, we do however show the range of cost elements, grouped by cost type (one-off and operational) which can be used by DNOs and other industry participants to inform their assessment of the necessary activities and costs associated with implementing the distribution restoration process developed through the Distributed ReStart project.

12. Learning Dissemination

All project workstreams have relied on a stakeholder-led approach to uncovering challenges, establishing existing capabilities and developing future options. This approach has been facilitated through the Knowledge and Dissemination (K&D) workstream. From the very start of the project, the K&D workstream has adopted a “co-creation” approach to sharing and disseminating new knowledge to industry.

Co-creation, in the context of Knowledge and Dissemination, refers to our product and service design process in which input from stakeholders plays a vital role in implementation being realised, as represented in Figure 12.

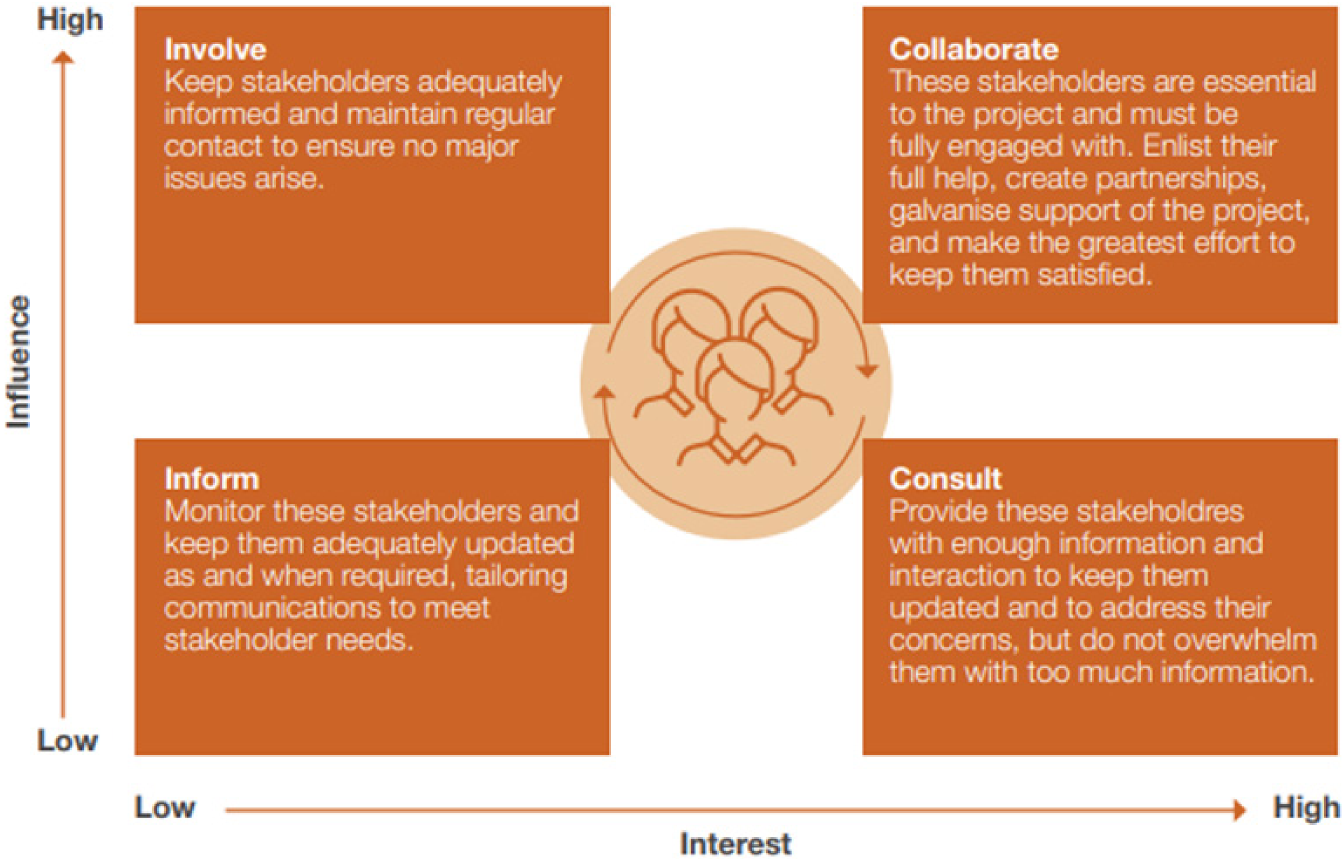

Figure 12: Co-creation principles[5]

The four main principles defined above demonstrate the key areas we use to ensure our messages are reaching our various stakeholders.

Through this, we demonstrate that all information is readily available and that we track and monitor feedback effectively.

5 Wesselingh, Frank & Gogaladze, Aleksandre & Impelen, Caroline & Raes, Niels. (2016). Deliverable D4.3 outreach programme established and approved – public version. 10.13140/RG

In the early stage, our engagement focused on building awareness, developing interest, and getting people involved. We did this through:

- industry engagement at ESO and external events
- accessible content on our website and social media
- email campaigns to our registered database
- 1:1 meetings, targeted workshops, conference papers.

As we moved through the project to the final stages, our focus became more defined by keeping our audiences informed and delivering outputs. This is being achieved through:

- quarterly Stakeholder Advisory Panel meetings
- industry engagement at the Energy Innovation Summit (EIS)
- creation of live trial reports
- creation of BAU procurement contracts
- email campaigns to our registered database which has grown to over 840 industry parties
- project webinars and podcasts.

The Dashboard Engagement Reports in Appendix 3 shows the level of engagement achieved by each workstream and milestone event.

12.1 Information Sharing Mechanisms

Pre-pandemic, knowledge and dissemination relating to the project was achieved by attending industry conferences, such as Utility Week Live, Energy Networks Innovation Conference (formerly known as Low Carbon Networks Innovation) and the Energy Innovation Summit (EIS). We also ran various webinars, keeping stakeholders abreast of our progress, as summarised below.

12.2 Transmission and Distribution Workshop – 12 September 2019

Distributed ReStart hosted an event inviting all DNOs and TOs in Great Britain to share their views on the future of restoration. This event focused on establishing existing capability across systems, telecommunications and organisations and the potential changes which may be required to enable project outcomes. Furthermore, a review of procurement methods and code requirements was conducted drawing on the expertise of networks owners and operators from across the country.

12.3 Annual Conference – 30 January 2020

The purpose of the Annual Conference 2020 was to meet with our stakeholders (and for them to meet the project team), inform them why we were doing this project, updating them on what we had done so far, and what we were planning to do. The main format of the day consisted of presentations and interview panels, and all the presentations can be found on the stakeholder engagement webpage on our website.

12.4 Design Stage Virtual Event – 30 June to 2 July 2020

This virtual event was groundbreaking as it was the first large electricity industry conference to be conducted virtually (across multiple days). We had people from the Future Energy Scenario (FES) team involved taking note of what we were doing so as to feed into their FES release in late July.

The three-day virtual event also updated our stakeholders on the latest design phase of the project including the technical, organisational, procurement and regulatory solutions to be tested in late 2020 and early 2021.

12.5 COVID-19 Knowledge and Dissemination Actions

Over the course of the project, the COVID-19 Pandemic imposed strict new rules governing human interactions, which, in turn meant that the K&D workstream had to adapt and apply creative solutions enabling the project to continue to engage and enthuse our large group of stakeholders.

As face-to-face events were no longer possible, the planned 2021 Annual Event was adapted to run as a 5-day series of podcasts known as "The Live Trials Stage". This included interviews with industry experts and members from the Distributed ReStart project team.

The podcasts, ground-breaking for the time, were designed to incorporate all workstreams and to present the project's journey through a series of challenging questions, giving the audience the opportunity to download and listen at a time that was convenient for them.

The podcasts remain hosted on Spotify and links to these can be found on our documents library webpage. Each podcast was hosted by people independent of the core project and included Trisha Lewis an actor, facilitator, business coach and podcast host with experience as a professional performer and speaker. Interviews were led by Simon Harrison, a member of the project's Stakeholder Advisory Panel who works as Group Strategic Development Director at Mott MacDonald.

The Live Trials Stage podcast event, detailed in Appendix 4, ran across 5 days in 2021, and provides details of the reach across the email campaign, webpage analytics, customer feedback and statistics on the level of engagement obtained.

The podcasts consisted of:

- *Podcast 1: High level summary on the progress of the project* – Why is it such an important project and why is so much at stake?
- *Podcast 2: To explore the role of design architects in the project* – How design architecture works, the assumptions, trade-offs and choices made.
- *Podcast 3: Panel discussion with external industry experts* – Distinguished external experts holding the project to account in all areas.
- *Podcast 4: The Live Trials – latest developments and progress* – An exploration of the latest findings and possibilities for a future roll-out.
- *Podcast 5: Technical and cyber challenges for systems and telecoms* – Unpacking the cyber-challenge and how to ensure system resilience.
- *Podcast 6: A new procurement approach for DER-based Electricity System Restoration* – Why do we need a new approach and how will codes work?

Full details of all the industry engagements that have been done across the span of this project can be found on our stakeholder engagement webpage.

12.6 Post-Pandemic (2021–date)

Since coming out of the global pandemic, the K&D workstream has gradually been able to interact more directly with our stakeholder community. The Stakeholder Advisory Panel (SAP) membership was reviewed as some members have moved to different roles across the industry, with new members joining in their place. On Friday, 28 October 2022, Distributed ReStart hosted the final, scheduled stakeholder advisory group meeting to discuss the panel's commentary to our draft Final Findings and Proposals report and how this should be incorporated and acted upon going forward, at which the following topics were on the agenda shown in Table 9:

Table 9: Stakeholder advisory meeting agenda

Start Time	Event	Owner
13:00	Welcome and introductions	Nick Jenkins
13:10	Project update	Mike Kenny
13:20	Redhouse Live Trial	Jack Haynes
13:40	Final Findings Report – commentary review	Nick Jenkins et al
13:50	South-East Region Tender update	Audrey Ramsay
14:10	GB Power System – latest developments around Scottish Network oscillations	Peter Chandler
14:20	Technical challenges post Distributed ReStart	Colin Foote
14.30	DNO engagement	Mike Kenny & Audrey Ramsay
14.40	Project Direction/Knowledge & Dissemination	Julie Balch & Mike Kenny
14:45	Meeting close and agree next steps	Nick Jenkins

Through hosting this form of event, we were able to understand and build on the existing capabilities, systems, and resources from across the industry. This greatly reduced the economic impact of our decisions and ensured the concerns of industry were appropriately addressed.

The outcomes of this engagement will be addressed via our new quarterly newsletters, starting in March 2023. There is scope for an extraordinary advisory group meeting if this was required for a particular topic to be discussed, with a focus on the Redhouse live trial technicalities.

The Distributed ReStart team would like to thank all delegates who have helped to deliver this, and all previous events and look forward to their continued engagement with project news in 2023.

The project also ran an annual event webinar in May 2022, which was widely attended by industry. The event titled "The Demonstration Phase: Distributed Restoration Works in Practice", took place on Wednesday, 25 May 2022. The slide pack presented, together with the Q&A and a recording of the event are all available on our documents library webpage.

We have an active distribution list of over 840 registered interested parties and use this as a channel to engage with people globally through email updates sharing pertinent project information and news, for webinars discussing specific project deliverables and challenges, and to promote attendance at specific industry events. Table 10 summarises the consultation and engagement activities made via the K&D workstream over this period.

Table 10: Key engagement events 2021 to date

Event	Description
Desktop exercises 27 May–06 Jul 2021	**What:** Three opportunities to experience a simulated electricity system restoration from DERs and help co-create the restoration process. **Who:** For DERs who could potentially offer a future electricity system restoration service, and for network operators and other interested stakeholders. **How:** The desktop exercises gave attendees hands-on experience of the proposed operational processes, and an opportunity to feed back into the processes and comms structures to help shape the future service.
Procurement and Compliance Test Procurement Event 02 Aug–06 Sep 2021	**What:** A Test Procurement Event for DERs who are interested in offering a future electricity system restoration service. The event was the equivalent of a "live trial" for the Procurement and Compliance workstream. **Who:** An opportunity for industry to get first-hand experience of the potential procurement process for DERs to deliver a electricity system restoration and give feedback to ensure the process works across various DER types.
ENIC 2021 12–15 Oct 2021	The Energy Networks Innovation Conference brought together the learning from over 60 UK innovation projects, providing an opportunity for knowledge sharing and networking between people who manage, develop, and implement innovation initiatives in the energy sector.
Podcast launch of the OST final report 30 Sep 2021	The final report on the conclusion of the desktop exercises was for the organisational component of the OST workstream. Highlights of the report include: • how Distributed ReStart will meet the requirements of the new Electricity System Restoration Standard (ESRS) for restoration timelines • how the process design has been shaped by stakeholder views at every stage, enabling optimisation and end-user consideration in its development • the restoration simulation, which was conducted with distribution network operators, transmission operators, the electricity system operator and more than 20 representatives from distributed energy resources (DERs) • the process design for the role played by automation, which incorporated feedback from refining the manual proposal in the Design Stage • how this process design involves an element of change for all organisations • a change impact assessment with recommended approaches to change management.
Podcast launch of the P&C final report January 2022	The Procurement and Compliance (P&C) workstream's final report podcast provided an understanding of the proposed procurement process and what will be required from DERs. Costs, commercial considerations, and the drafting of industry codes to future proof the designs were discussed. It also shared insights and challenges around the full procurement process and the transition to business as usual.
The Demonstration Stage: distributed restoration works in practice May 2022 – Annual event webinar	Our third and final annual event covers our "proof of concept" outputs including our live trial in Galloway, Scotland. Attendees were able to watch presentations from the project's workstream leads, engineers and design architects, including a Q&A session. This webinar also covered the successful Factory acceptance testing (FAT) of a Distribution Restoration Zone Controller (DRZC).

Energy Innovation Summit 28–29 September 2022	Distributed ReStart was among several innovation projects showcased on the ESO stand. There was an opportunity for conference attendees to book dedicated 1 to 1 sessions with the project team, on a variety of topics such as: • technical aspects of the project and any plans for moving forward in this area • revenue opportunities, technical requirements, precedents, impact on day-to-day operation • the application of digital communications such as private wireless (mobile standards) for orchestrating black and distributed restarts • technical parameters of the proposed DRZC solution and preferred commercial delivery models for future projects *(Assessment of Power Engineering – Aspects of Black Start from DER Part 2)*. • Standardisation Requirements (P&C: *Distribution Restoration future commercial structure and industry codes recommendations* and cyber: *Organisational, Systems and Telecommunications Design Stage II*).
Closedown event webinar: final conclusions 30 November 2022	This interactive webinar was the conclusion of our mandatory Ofgem deliverables, where we presented the final conclusions and learnings. Attendees were able to engage with the project's workstream leads, engineers and design architects.

12.7 Information-Sharing Requests

It is clear that the external stakeholders (from a project perspective, we included TOs, DNOs, DERs as well as our project partners, SPEN and TNEI) had a direct and relevant desire to understand the fundamental issue which the project had to embrace. To this end, and to directly align with the South East & Northern tender processes that started in June 2022, whilst this project was still concluding its key findings and recommendations, we embarked on a series of DNO engagements via a "roadshow", whereby:

- we engaged each DNO in a dedicated 1.5–2 hour Microsoft Teams meeting with key members of staff, at which the workstream leads (or their delegates) presented their main findings that were felt to be most relevant to the particular DNO. All presentations elicited a wide range of Q&A, which reflected the high-level of interest in our project amongst the DNO community
- these sessions were recorded and shared with each DNO in turn. Due to the nature of the discussion and to protect people's right to privacy, we have created a consolidated DNO engagement video, and have documented the *Q&A* from all the sessions, on our website.
- we also offered to engage with the with the Independent Networks Association, the representative body overseeing independent network operators (IDNOs). We had positive confirmation that several members subsequently attended the ESO led South-East tender webinar that followed on from our engagement.

Other Engagements and Information Sharing Opportunities

- Across the project's lifespan, many team members have been asked to speak about the project at external industry events and conferences, such as the Prospero Events webinar "Distribution Systems Automation", which the OST lead and systems specialist attended to present the project's key findings in this important area. In addition, project members have submitted papers to CIGRE and have subsequently been accepted to present at these prestigious events. Following the successful desktop exercises, the team put together a paper on the *Development and validation of new organisational Models and Systems for DER led Restoration*, which was accepted and presented during this year's event on 28 August and 2 September in Paris. Please see Appendix 2 for the poster produced for the session. The team also hosted a global webinar to the Energy Systems Integration Group (ESIG) covering the project's work and detailing the findings of the Redhouse live trial.

- The project's collaboration with external experts has resulted in publications in related areas of research and demonstration. One example is this paper resulting from the work undertaken by Iberdrola Innovation Middle East and Strathclyde University, which has been accepted for publication in a prestigious peer-reviewed journal: A. Alassi, K. Ahmed, A. Egea-Alvarez, C. Foote, *Transformer Inrush Current Mitigation Techniques for Grid-Forming Inverters Dominated Grids*, accepted for publication in *IEEE Transactions on Power Delivery*.

Development Feedback for this Report

In developing this *Closedown Report,* the project has requested and received extensive feedback from our project members, past and present, our partners SPEN and TNEI, our extensive stakeholder community (some 800+ members and still increasing) as well as the energy industry bodies (mainly the ENA) and industry representatives in general.

In addition, we commissioned network licensee Scottish & Southern Energy Networks (SSEN) to review this report and provide their assessment in accordance with Section 8.38–8.40 of the *Electricity Network Innovation Competition Governance* document.

Please see Appendix 1 for SSEN's assessment of this Closedown Report.

13. Key learning documents

13.1 Project Deliverables

In our *Final Findings and Proposals* report, Section 4.0, Knowledge and Dissemination, Table 7 gives a comprehensive list of all of the reports produced by this project since inception in 2019.

In order to fully comply with the NIC governance requirements, Table 11 gives a list of all project deliverables that have been successfully met, together with a short summary of the content, allowing other parties to judge whether the document will be of use to them.

Table 11: Project deliverables met

Reference	Project Deliverable	Deadline	Evidence	Link to Deliverable
1	Organisational, Systems and Telecommunications viability assessment of the capability to deliver the high-level concept.	08/11/2019	Report documenting the outcomes of analysis for: • resilience assessment of telecommunications • resilience and capability assessment of systems relevant to electricity system restoration from DER • capability assessment of organisational structures and skills. The conclusions of the report have highlighted the main areas of challenge that will be the focus of the Design Stage and later stages to address.	*Organisational, systems and telecommunications viability report*
2	Design of process, roles and requirements, and systems and telecommunication requirements to control and coordinate a power island created from electricity system restoration from DERs.	02/10/2020	Proposal of how electricity system restoration from DER will operate as a process, including: • a process map with task allocations • organisational structures including roles and responsibilities • requirements for systems or tools with initial outline design concepts • telecommunications functional requirements.	Part I report focusing on process design and communication interfaces: *Organisational, Systems and Telecommunications Design Stage I* Part II report focusing on telecommunications functional requirements and expanding on this original deliverable to include a cyber security assessment: *Organisational, Systems and Telecommunications Design Stage II*

3	Refine the Organisational, Systems and Telecommunications requirements by testing key areas and capturing the learning.	30/09/2021	Undertake a desktop exercise to test the organisational capability for the process, including systems and telecommunications where appropriate. Capture learnings from the exercise within an update to the key Deliverables 2 report. Work with manufacturers to complete designs of systems and telecommunications (see links to reports 1 and 2 above) to enable the timely delivery of the power system trials. Where appropriate, undertake offline tests to prove capability of systems via hardware in-the-loop testing.	*Operating a Distribution Restoration Zone September 2021*
4	Assessment of electricity system restoration from DER viability in GB and proposed functional requirements.	31/7/2019	Report presenting the outcomes from the Viability Stage of the Power Engineering and Trials (PET) workstream including; • the choice of case studies and the potential options for network re-energisation in each case • initial proposals for the functional and testing requirements to apply for electricity system restoration from DER • the potential for roll-out of the method across GB • industry consultation to test whether the report is clear, comprehensive and justifies further work.	*Report on the viability of restoration from DERs (Redacted version)*
5	Technical and financial proposals for demonstration.	31/7/2020	Report presenting the conclusions from detailed assessment of the power engineering aspects of electricity system restoration from DER, using the case studies as examples, and make firm proposals for live trials. The report will be supported by the results of power system studies, shared subject to confidentiality restrictions relevant to each DER. The report will be assessed in terms of completeness and clarity and whether it allows decisions to be made on live trials by the Steering Group and DER participants.	Part 1 report: *Assessment of power engineering aspects of Black Start from DER Part 1* Part 2 report: *Assessment of Power Engineering – Aspects of Black Start from DER Part 2*

6	Demonstration of electricity system restoration from DERs.	20/12/2021	This deliverable marks the completion of the power engineering live trials (as approved by the Steering Group). Note: due to technical and legal delays to the live trials, this section was delivered in three reports.	Part 1 report (fully meets Deliverable 6 – Demonstration of black start from DERs): *Demonstration of Black Start from DERs (Live Trials Report) Part 1* Part 2 report – Demonstration of black start from DERs (Live Trials Report): *Demonstration of Black Start from DERs (Live Trials Report) Part 2* Part 3 report – Demonstration of black start from DERs (Live Trials Report): *Demonstration of Black Start from DERs (Live Trials Report) Part 3*
7	Functional requirements for procurement and regulation.	8/11/2019	Report on procurement options and the criteria for determining the preferred option. Report on commercial design of the service (e.g. term, obligations delivery and payment etc.) with consideration of the learnings from the organisational and technical workstreams. Report on gaps and blockers in relevant codes and license conditions that will need to be addressed to enable proposed new electricity system restoration services.	*Functional Requirements for Procurement & Compliance*
8	High-level outline of contract terms and regulatory arrangements.	02/10/2020	Report on detailed design of the procurement process and contractual arrangements based on technical, procurement and regulatory options. Report on potential regulatory and funding arrangements, and consequential changes to relevant codes and licence requirements.	*A high level outline of commercial and regulatory arrangements*
9	Final version of procurement generic standard terms.	20/12/2021	Generic standard terms of contract by which a service for electricity system restoration could be procured reflecting industry engagement. These will include the contracted obligations on each party required in the delivery of the service and the necessary commercial arrangements.	Main body report: *Distribution Restoration future commercial structure and industry codes recommendations* Appendices: *Appendix 1 Stakeholder Engagement* *Appendix 2 Draft Distribution Restoration Contracts* *Appendix 3 Codes Legal Text Drafts* *Appendix 4 Distribution Restoration Procurement Process Map*

10	Final proposals for functional and testing requirements for electricity system restoration from DER.	End of project	Report on learning and proposed approaches from project activities, across all workstreams and external engagement. This will form the basis for transition to business as usual. If the concept is successful, this will include: • finalised process design with consulted organisational structures, roles and responsibilities • finalised functional specifications for telecommunications and systems • finalised technical generic DER/ network/concept requirements • finalised generic contractual terms for procurement. If the concept cannot be successfully proven, the above will be prepared documenting the gaps.	*Final Findings and Proposals for Electricity System Restoration from DERs*
Common project deliverable	Comply with knowledge transfer requirements of the governance document.	End of project	Annual project progress reports which comply with the requirements of the governance document.	Jun 2019: Project progress report Dec 2019: Project progress report Jun 2020: Project progress report – Redacted version Dec 2020: Project progress report – Redacted version June 2021: Project progress report Dec 2021: Project progress report
			Completed *Closedown Report* which complies with the requirements of the governance document.	This report
			Evidence of attendance and participation in the annual conference as described in the governance document.	Visit stakeholder engagement on our website

13.2 Introduction to the 2019 NIA Project – Electricity System Restoration from Non-Traditional Technologies

Immediately prior to the commencement of the Distributed ReStart NIC project in 2019, a four-month NIA project was undertaken. The study “Black Start from Non-Traditional Generation Technologies” focused on conducting some exploratory work to feed into Distributed ReStart concerning the restoration capabilities of different non-traditional technologies, lessons learnt from operational islanded systems and the potential for variable wind generation to participate in system restoration. The Technology Readiness Level (TRL) scores that were concluded were based on information/forecasts that were available at the time. Technologies such as batteries, EVs/V2G, wind and solar have moved on rapidly since then and their TRL scores may have advanced. Three stand-alone reports were produced and published:

- *Technology capability and readiness for distributed restoration*
- *Power Island Strength and Stability in support of Black Start*
- *Case study: Wind variability*

A review of the NIA project outcomes has been conducted to reflect on these and how some of the key issues, challenges or opportunities highlighted at that early stage have been progressed through the work done in the NIC project. A review of other developments across the industry, e.g. through the Resilience as a Service (RaaS) project, which has a few key synergies with Distributed ReStart, has also been carried out.

13.3 Key Outcomes of the NIA project

The capability and readiness of several established and emerging distributed technologies to provide restoration services was assessed through the NIA project by undertaking technology reviews and complementing this with an extensive stakeholder engagement exercise. Each technology/site type was measured against the existing technical requirements for electricity system restoration provision as per the Grid Code and assigned a technology readiness level (TRL) across the various requirements. This allowed the capabilities to be clearly defined and any gaps to be identified. Figure 13 shows the performance matrix compiled from the assessment, noting the capability of each technology type/site across three distinct phases of a restoration event (shutdown, electricity system restoration, restoration) with Figure 14 noting the scoring scale.

Restoration event timeline	Site capability	Non-Traditional/DER Technology						
		Large Onshore Wind (>30MW)	Small Onshore Wind (<30MW)	Commercial Solar (PV)	Battery Energy Storage	Demand Side Response (I&C)	Electric Vehicles/V2G	Synchronous DER
1. Shutdown resilience	Plant resilience (shut-down, standby)	2	2	2	2	4	4	1
	Comms and control resilience	2	3	3	3	5	5	2
2. Black start performance	Self-starting of plant	3	3	3	2	5	5	1
	Grid-forming capability	3	3	3	2	5	5	1
	Demand block loading	2	3	4	3	3	5	1
	Reactive power support	1	1	4	1	5	5	2
	Frequency control	1	1	1	1	5	5	2
	Dispatchability	2	3	4	2	1	5	1
3. Restoration capability	Power Island joining and support	2	2	2	1	2	5	1
	Sustainability (reliability)	2	3	4	3	1	5	1

Figure 13: Performance matrix of technology/site capability to provide restoration services

Score	Descriptor
1	Majority have proven capability, commercial operation
2	Majority have some capability, pilot/ testing phase
3	Majority have limited capability, under development
4	Majority have low capability, concept phase
5	Majority have no capability, research stage

Figure 14: Capability scoring scale

The performance matrix showed that:

- **Synchronous DERs** have useful capabilities across all phases of restoration and is the only technology able to self-start and participate in the formation of a power island.
- **Battery storage and large wind sites** are capable of meeting most of the restoration services however there remained some gaps in communications resilience, self-start capability and availability of resource.
- **Small wind sites** typically have a lower level of service provision (compared to large wind) due to less onerous connection conditions placed on them.
- **Solar PV** has a lower performance level than large wind and battery storage mainly due to the inverters installed. Cost has a huge influence on design choice and so their capability is limited compared to other larger developments.
- **Industrial and commercial (I&C) demand side response (DSR)** can make useful contributions at the later stages of restoration, for example, in the block loading phase due to their dispatchability.
- **EVs** (including vehicle to grid) are not currently deployed widely enough to be considered as a service supplier for system restoration.

An additional performance matrix was compiled to reflect the capability of sites co-located with battery storage. As seen in Figure 15, sites where wind or solar PV sites are co-located with battery storage can offer an improved service provision through their cumulative capabilities.

Restoration event timeline	Site capability	Co-located DER technology		
		Solar PV + BESS	Small onshore wind + BESS	Large onshore wind + BESS
1. Shutdown resilience	Plant resilience (shut-down, standby)	2	2	2
	Comms and control resilience	3	3	2
2. Black Start performance	Self-starting of plant	2	2	2
	Grid-forming capability	2	2	2
	Demand block loading	2	1	1
	Reactive power support	1	1	1
	Frequency control	1	1	1
	Dispatchability	2	2	1
3. Restoration capability	Power island joining and support	1	1	1
	Sustainability (reliability)	2	1	1

Figure 15: Performance matrix of co-located sites

The most significant improvement is seen in the capability of solar PV sites to offer restoration services when combined with battery storage, although there does remain some challenges with communications and control infrastructure and resilience.

Considering the performance matrix in the context of technology readiness, Figure 16 details the TRL[6] levels that were assigned to each of the technology types/sites for providing restoration services across the three stages of a restoration event. A TRL was assigned to these capabilities to indicate to National Grid ESO, and industry in general, the challenges and barriers that currently inhibit reliable participation of these non-traditional technologies.

Technology	Shutdown resilience TRL	Black start performance TRL	Restoration capability TRL
Large wind	6	6	8
Small wind	5	6	7
Solar PV	5	4	6
Battery storage	5	8	8
I&C DSR	4	4	4
Other (synchronous DER)	6	8	9
Electric vehicles and V2G	4	2	2

Figure 16: TRL assignment of technology types/sites

Recognising that a TRL of 9 indicates a technology or product is considered "operational", it is clear there are gaps in capability for the technologies assessed. And while it is acknowledged that the likelihood of these non-traditional technologies being able to provide the full suite of restoration services required in a full or partial shutdown is low, there is definite appetite to improve the TRL of some capability such that the vast distributed energy resources connecting to the power system can provide a strong alternative to the conventional power stations currently relied upon for these services.

Several key technical barriers were identified, based on the review and stakeholder engagement. These, alongside the proposed mitigations and interventions, are highlighted in Figure 17.

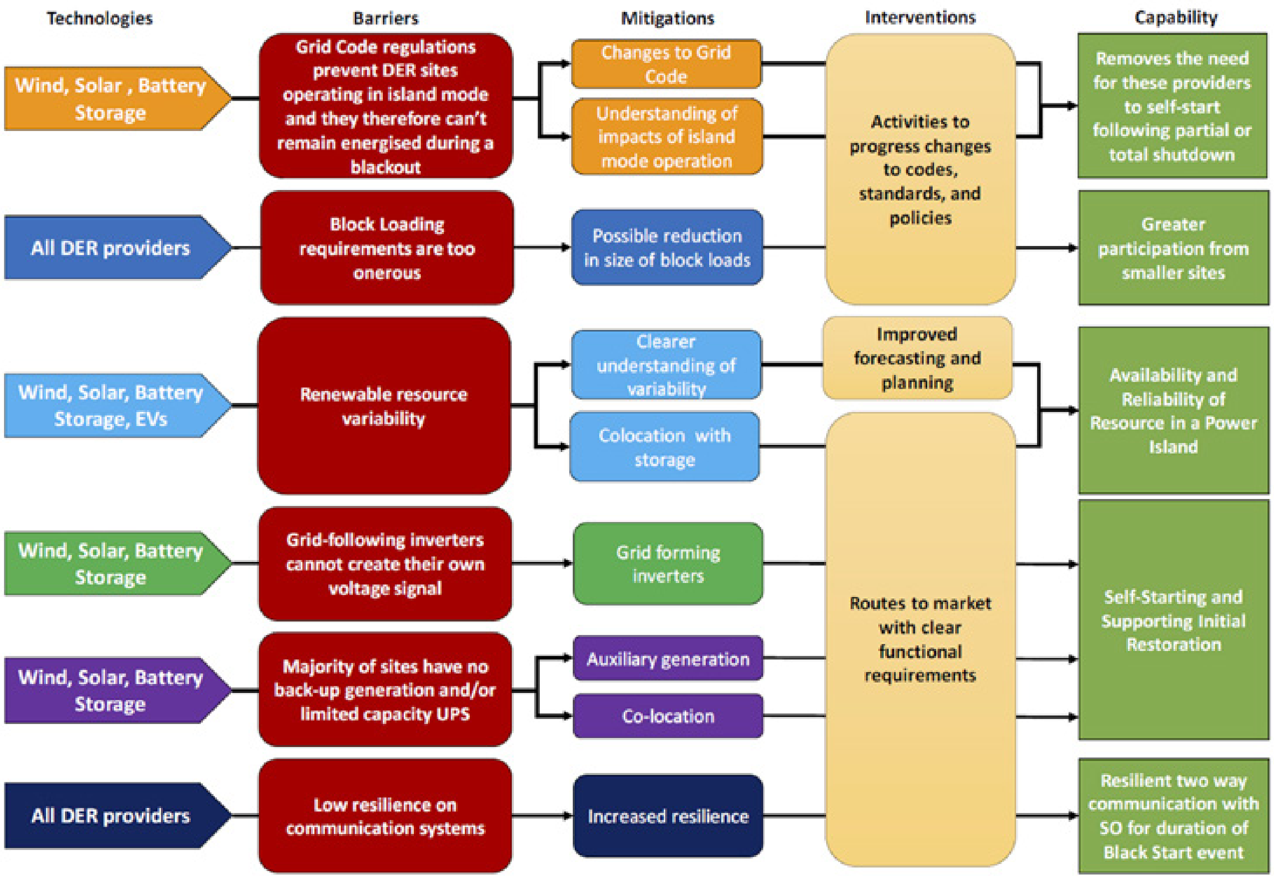

Figure 17: Barriers and mitigations for non-traditional technologies providing restoration services

6 Source: NDA Report *"Guide to Technology Readiness Levels for the NDA Estate and its Supply Chain"*, 2014

While the Distributed ReStart NIC had clear objectives from the outset, the outcomes of the NIA project formed a clear basis of the key questions the project should seek to answer. The following sections demonstrate how several of these barriers have been addressed through the NIC project and reflect the significant steps forward in enabling system restoration to be facilitated by distributed and non-traditional generation technologies.

13.4 Project Progress on Addressing Barriers Identified through the NIA Reports

Through the Distributed ReStart project, many barriers identified in the NIA project regarding the provision of system restoration services from non-traditional, distributed, and renewable technologies have been addressed, or where wider industry changes are required, steps have been taken to begin to address them. From Figure 17, the progress made on addressing each of the barriers is detailed in Table 12. It is important to note that as the Distributed ReStart project has progressed, so too has the understanding of how distributed resources could play a role in system restoration.

Table 12: Progress made in addressing barriers

Barrier	Progress made in addressing barrier through the Distributed ReStart project
Grid Code Requirements	Through the Procurement and Compliance workstream of the project, a full review of existing codes and standards was undertaken to identify specific clauses or sections which directly or indirectly prevent DER from participating in a restoration. A focused Codes Working Group was formed which then methodically revised the various codes (Grid Code, Distribution Code, STC etc.) to be more inclusive to different technology types and sizes. A key part of this was in distinguishing between anchor services and top-up services. Where previously one single large conventional power station was able to provide the full suite of services, there are provisions in the codes now for these services to be disaggregated such that sites can offer restoration services on a more discrete basis. This is supported by a commercial procurement service design framework[7]. As an example, anchor DER (such as a synchronous power station) may provide the self-start capability and create the required network conditions, i.e. a voltage signal, then other DER such as wind could latch onto this voltage signal and form a power island with the anchor DER and other DERs on the network. Sequential energisation of the network could then be carried out. This principle has been successfully tested through the live trials of the Power Engineering and Trials workstream.[8]
Renewable Resource Availability	No direct advancements on the analysis conducted in the NIA project on wind resource availability for the purposes of participation in a restoration has taken place (it is out of scope for the Distributed ReStart project). However, the analysis performed in the NIA project is easily repeatable using the developed model. It would be straightforward (considering available data sets) to examine the resource availability of different renewable sources, and also their co-location with battery storage.
Grid-Forming Inverters	The Power Engineering and Trials workstream recognised the value of grid-forming inverters for the purposes of restoration. A range of investigative modelling and analysis was commissioned and reported upon, highlighting the opportunities and challenges[9]. Furthermore, a third live trial (the project was only required to complete two live trials) has been planned for mid-2023 at Redhouse to test a battery storage facility with a grid-forming inverter installed. The results will be reported upon completion of this trial.
Back Up Generation and UPS Low Resilience Communications	The Organisational, Systems and Telecoms workstream focused on the organisational process design(s) required to enable a restoration from DER and a key part of this was in defining the telecoms and resilience requirements for those DER to participate in a restoration. Functional specifications for the operational telecommunications were developed and refined[10] throughout the project and was supported and enhanced extensive stakeholder engagement with wider industry.

7 Distribution Restoration future commercial structure and industry codes recommendations

8 Distribution Restoration future commercial structure and industry codes recommendations

9 Tx Energization and Conventional Black Start Resources Grid Forming Converters Control for Black Start Applications

10 *Organisational, Systems and Telecommunications Design Stage II*, Distributed ReStart, December 2020

It is clear from the table above that significant progress has been made in addressing the barriers identified at the start of the project and by the NIA technology capability and readiness study. The Distributed ReStart project has effectively proved the concept that system restoration can be achieved using DER through live trials. Commercial and contractual agreements have been developed alongside Grid (and other) Code amendments to enable the participation of different technology types and sizes. Organisational arrangements have been proposed to ensure all participants are aware of their responsibilities in a restoration event and ultimately the solution is transitioning into business as usual.

13.5 Other Industry Developments

While significant advancements have been made within the Distributed ReStart NIC project in de-risking and testing DER for use in a restoration, there has also been wider industry activity in this space.

SSEN Resilience as a Service NIC project

SSEN's Resilience as a Service (RaaS) project is seeking to improve the operational resilience of distribution networks in rural and islanded areas that experience higher than average interruptions. They are doing this through the development and trial of a new market-based solution using battery storage technology and DERs to restore power to customers in these areas following an event or a fault[11]. There are notable synergies with Distributed ReStart, primarily the use of DERs to sustain power islands. The RaaS project is working towards live trials at this time, but system studies conducted in preparation for these live trials[12] indicate that battery storage (BESS) operating in grid-forming mode can automatically restore a network which has lost supply due to a fault on the higher voltage network, operate successfully in island mode and then transition from grid forming into grid-following operation to re-synchronise with the main grid supply.

Scottish Power Renewables Dersalloch Wind Farm Electricity System Restoration Trial

In 2020, Scottish Power Renewables (SPR) and Siemens Gamesa Renewable Energy (SGRE) deployed grid-forming technology (also known as virtual synchronous machine (VSM) technology) on their 69 MW wind farm to regulate frequency and voltage and enable the wind farm to re-energise part of the grid[13]. This project highlighted the capability of renewables, particularly wind farms, to play an important role in the future of system restoration. The addition of a BESS to the Dersalloch site will further boost the site's capability to support critical system services.

Research, Development and Studies on Restoration from DER

Worldwide, there has been continued interest in investigating the effectiveness of using DER to provide system restoration services. The National Renewable Energy Laboratory (NREL) in the US has published literature on the studies they have conducted on Electricity System Restoration of Power Grids with Inverter-Based Resources[14], and the International Journal of Electrical Power and Energy Systems has published several journal papers related to load restoration and control philosophies for islanded networks and microgrids[15]. This is just a snapshot of the huge amount of activity in this increasingly critical area of power system development as more and more renewables and converter connected technologies are deployed.

13.6 Project Progress Reports (PPRs)

Links to all PPRs are listed in Table 7 on page 33 of our *Final Findings and Proposals* report.

11 Innovation Portfolio | Scottish & Southern Electricity Networks

12 *Resilience as a Service (RAAS) Evaluation of Islanded Network Black Start Capability*, SSEN, October 2021

13 Scottish Power Renewables

14 *Blackstart of Power Grids with InverterBased Resources*, NREL, February 2020

15 *International Journal of Electrical Power and Energy Systems,* Volume 133, December 2021

14. Data Access Details

Details on how network or consumption data arising in the course of a NIC or NIA funded project can be requested and the terms on which such data will be made available by National Grid can be found in our publicly available *Data sharing policy related to NIC/NIA projects*.

It is recommended that the prospective data user first contacts the relevant National Grid ESO innovation manager by e-mail at box.SO.Innovation@nationalgrid.com to discuss informally the feasibility of the proposed data request.

National Grid Electricity System Operator already publishes much of the data arising from our NIC/NIA projects on the Smarter Networks Portal. You may wish to check this website before making an application under this policy, in case the data which you are seeking has already been published.

15. Material Change Information

Through project delivery, the project plan has been adjusted by a number of notable changes, although only one resulted in a material change request (MCR):

1. Second half 2020 – In the early assessment of viability of the distributed restoration concept, we identified that establishing, growing, maintaining, and restoring a distribution power island at distribution level is likely to require some level of automation for the process to be technically and operationally viable. The project introduced the concept of a DRZC to describe the system(s) that will enable monitoring, control, and coordination of a range of DER, and network resources to provide restoration services. Having engaged four technology companies to produce DRZC designs and used those to confirm feasibility of the approach and produce a generic functional requirements specification, the project team decided to progress to the build and test of a prototype DRZC. This extension of project scope within existing budget was possible due to the efficiency of delivery early in the project.

2. June 2021 – formal letter requesting an extension to June 2022. The core reason for the change was that we were unable to complete the Chapelcross trial as originally planned for September 2021 due to a delay in original equipment manufacturer (OEM) pre-works. Our supplier notified us that they were unable to provide the necessary resources to complete the feasibility assessment for the Steven's Croft biomass generator. In response, we initially presented the most viable options to our project steering committee and the preferred choice was to re-schedule the live trial to Apr-May 2022 and subsequently extend the project end date so that we could include these results.

3. March 2022 – formal letter to Ofgem requesting an extension to December 2022, to allow us to complete a minimum of two live trials at Galloway and Chapelcross, plus the two remaining GE reports for the FAT and HVDC testing of the prototype DRZC and subsequent closedown activities.

4. September 2022 – formal material change request to Ofgem requesting an extension beyond March 2023, to October 2023 and funding-related requests for the Redhouse live trial (BESS) as follows:

   - Phase 1 – Proving grid forming capability of battery energy storage system (BESS) on third party network only.
   - Phase 2 – Proving grid forming capability of BESS and ability to energise 33 kV and 132 kV network/ transformers.
   - Phase 3 – Include a solar PV generator within tests to demonstrate ability of multiple converter-connected DERs to form an islanded grid.
   - Implement prototype DRZC to demonstrate ability to control the power island and respond to disturbances.

16. Contact details

Contact Name (until 31/10/2023)	Contact Details (email and postal address)	Role
Mike Kenny	michael.kenny@nationalgrideso.com restart@nationalgrideso.com National Grid ESO St Catherine's Lodge, Bearwood Road, Sindlesham Nr Wokingham, Berkshire, RG41 5BN	Project Lead
Julie Balch	julie.balch@nationalgrideso.com restart@nationalgrideso.com National Grid ESO St Catherine's Lodge, Bearwood Road, Sindlesham Nr Wokingham, Berkshire, RG41 5BN	K&D/PMO Lead

Contact Name (post 31/10/2023)	Contact Details (email and postal address)	Role
Vitor Soares	vitor.soares@nationalgrideso.com National Grid ESO St Catherine's Lodge, Bearwood Road, Sindlesham Nr Wokingham, Berkshire, RG41 5BN	Electricity System Restoration Manager
Roopkamal Phull	roopkamal.phull@nationalgrideso.com Faraday House, National Grid, Warwick Technology Park Gallows Hill, Warwick, CV34 6DA	Senior Restoration Contracts Lead

17. Project Delivery Plan

At the start of the project in January 2019, the high-level project plan was for delivery in two broad phases, Development and Demonstration, as shown in Figure 18.

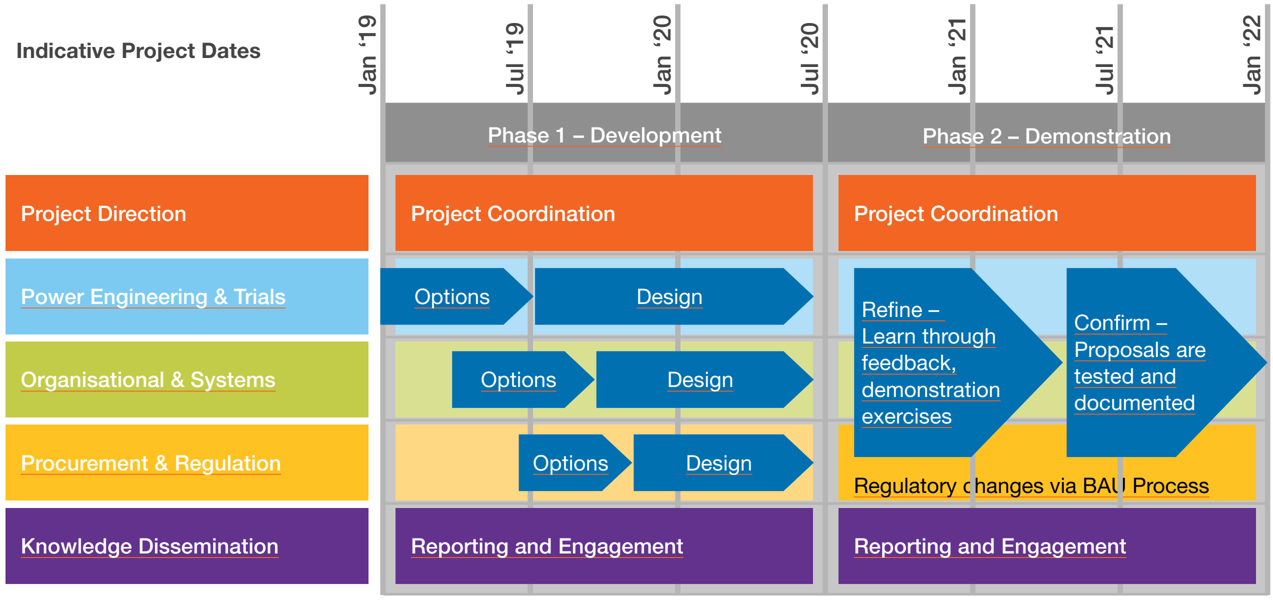

Figure 18: Structure of electricity system restoration from DER project

The Development Phase was split into two stages, Options and Design. The Options Stage identified, and prioritised challenges arising in each work stream area and went on to determine the basic viability of the method before effort was invested in detailed analysis or developing new processes. The Design Stage developed the options in preparation for testing, across all three workstreams. Industry consultation on proposed designs was achieved through the publication of the OST, PET and P&C Design Stage reports in 2020.

The Demonstration Phase was split into two stages, Refine and Test. The aim was to demonstrate the delivered benefits of the designed solutions through a series of desktop exercises, offline testing, live system trials, and a mock procurement event. Each of these incorporated their feedback into the final designs. By testing the designs in this iterative manner learning from each stage was be maximised, whilst minimising impacts on customers.

Overall, the project has managed to successfully deliver the required Ofgem objectives, utilising this initial project delivery framework, albeit with a now extended timeline, due to delays in setting up and delivering the three live trials at Galloway, Chapelcross and Redhouse.

As can be seen from the original project plan, the initial end date was planned to be end of January 2022, which was then further revised to 31 March 2022 (submission of the Final Proposals for Functional and Testing Requirements – Project Deliverable 10). To accommodate the minimum of two live trials (Demonstration of Electricity System Restoration from DER – Project Deliverable 6), the project has been extended twice, to June 2022 and then to December 2022. Two live trials were successfully completed and the relevant trial reports published.

As mentioned previously, the Redhouse trial was unable to run in October 2022 as planned, so a material change request was submitted to Ofgem in late September 2022 to formally request an extension for the project. Ofgem formally approved the request, in a written response, to the additional extension to October 2023, to accommodate the third live trial at Redhouse, which successfully tested the use of a BESS with grid-forming technology (converters). Although not required to meet Ofgem Deliverable 6 in our *Project Direction NIC* document, we felt that it was imperative to prove to ourselves, our project partners, the wider industry, Ofgem and UK consumers that this technology was feasible and could be proven to support the Electricity System Restoration Standard (ESRS) to be implemented by December 2026.

The latest project plan below has been updated to show the key activities required to deliver the Redhouse live trial over the concluding 12 months of the project.

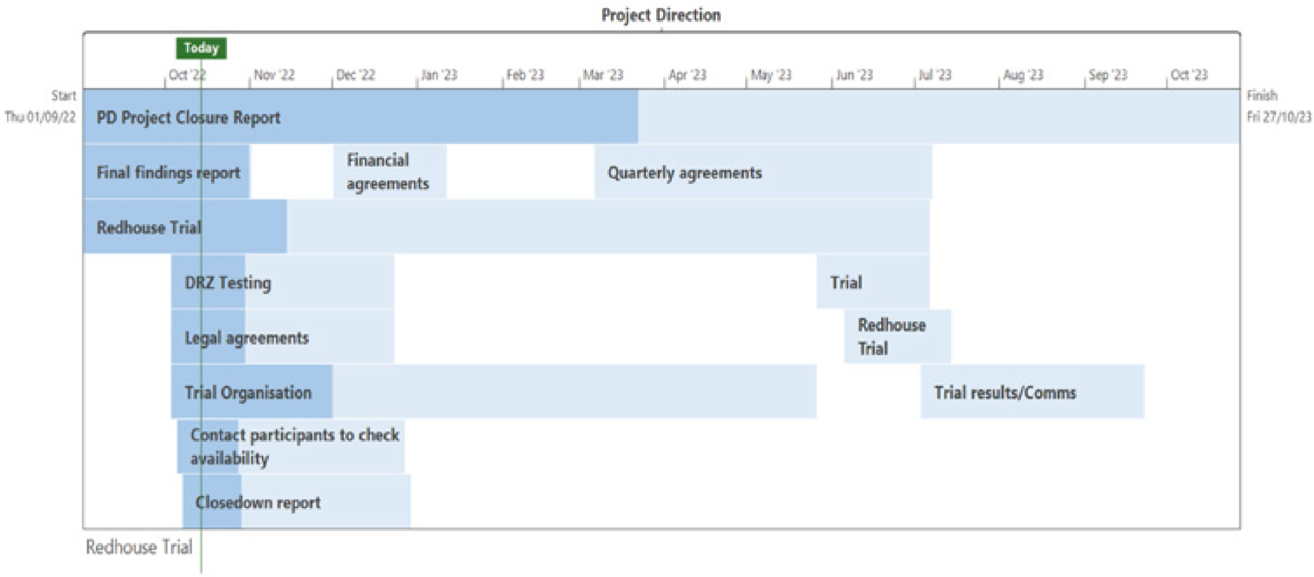

Figure 19: Distributed ReStart project plan for the Redhouse live trial extension

Appendices

Appendix 1: SSEN Distribution Peer Review Letter

Scottish & Southern Electricity Networks

Michael Kenny
National Grid ESO
St Catherine's Lodge
Bearwood Road
Sindlesham
RG41 5BN

Sarah Rigby
SSEN Distribution
No. 1 Forbury Place
Forbury Road
Reading
RG1 3JH

7 December 2022

Dear Michael,

SSEN Distribution represents the distribution licenses of Scottish Hydro Electric Power Distribution plc and Southern Electric Power Distribution plc, and are the electricity Distribution Network Operator (DNO) responsible for delivering power to over 3.8 million homes and businesses across central southern England and the north of Scotland. We serve some of the most diverse and unique geographies across the UK, and have a clear focus on developing the flexible electricity network vital to achieving net zero.

We have reviewed the Close Down report for the Distributed ReStart project and confirm that it provides clear evidence of the benefits that the project has brought to understanding and de-risking the use of Distributed Energy Resources (DERs) to restore power in the unlikely but significant event of a total or partial shutdown of the GB National Electricity Transmission System (NETS). The report is clear and understandable, and provides a means by which both Network Licensees and other industry stakeholders, such as DER owners and operators, can access information to evaluate how to develop and implement the processes and capabilities necessary to deliver the required services.

Engaging and effective stakeholder engagement throughout the project has supported and informed development of the proposals, to provide a solution which incorporates all parties with a role in facilitating and participating in distribution restoration.

By providing clear thinking on the necessary organisational design, roles and responsibilities; the power engineering and integration considerations; the systems and telecoms requirements; and the procurement & compliance aspects of implementing Distribution Restoration Zones, the project has addressed key challenges to demonstrate how this new approach can be incorporated into business as usual activities for restoration of the National Electricity Transmission System.

We recognise that the ground-breaking learning from the simulations, real world tests and stakeholder engagement activities through the Distributed ReStart project are of significant value to the industry in maintaining efficient and economical Electricity System Restoration (ESR) services as the energy system decarbonises and decentralises.

Scottish & Southern Electricity Networks

We look forward to ongoing collaboration as National Gird ESO progress with tenders for restoration services which now include the option of services from DERs, and continue their engagement with other parties, such as DNOs, in implementing the technical, organisational and commercial changes identified through the project.

Yours sincerely,

Sarah Rigby

Innovation project Delivery Manager

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C2 PS1

System Operation and Control

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tnei

Development and validation of new organisational models and systems for DER led restoration

C. SALTER[1], , M. KENNY[1], D. NNABUIFE[1], P. CHANDLER[1],
D. GÜTSCHOW[2], D. CHAKRAVORTY[2]
[1]National Grid ESO, [2]TNEI services

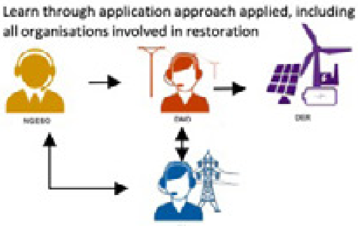
Motivation

- As the GB electricity market becomes more decentralized, decarbonized and digitalized so the approach to Power System Restoration must change
- Work undertaken as part of the Distributed ReStart project developed organizational models, telecommunications requirements and control systems to enable resilient control of distributed energy resources under a system restoration scenario.

Method and Approach

- Extensive consultation with all organizations involved in GB restoration was used to baseline and identify risks
- Parallel development of technical requirements including telecommunication and cyber security capabilities was undertaken.
- Real world tests were conducted through desktop exercises, live network trials and system prototype real time digital simulation with hardware in the loop tests

Learn through application approach applied, including all organisations involved in restoration



Objects of investigation

- Create an end- to- end specification for the power systems, organisational, telecommunications, network code and procurement requirements to facilitate restoration from distributed assets
- Develop an organisational structure to facilitate the power systems findings and maximise the restoration speed whilst at minimum total cost to the end consumer
- Develop a functional specification for the control systems required to support the power systems and organisational capability gaps
- Define the functional telecommunications requirements for this process
- Demonstrate the effectiveness of the organisational designs through application using desktop exercises
- Demonstrate the effectiveness of the control system through real time digital simulation on a prototype

Experimental setup & test results

- A custom electricity simulator was developed enabling remote access to a common platform for DNOs, ESO, TO and DER. Feedback was collected to identify improvements and blockers in the process design
- 4 vendors were selected to develop a control system specification, the outputs of these were collated to create a functional specification from which a single vendor then developed the prototype for HiL testing

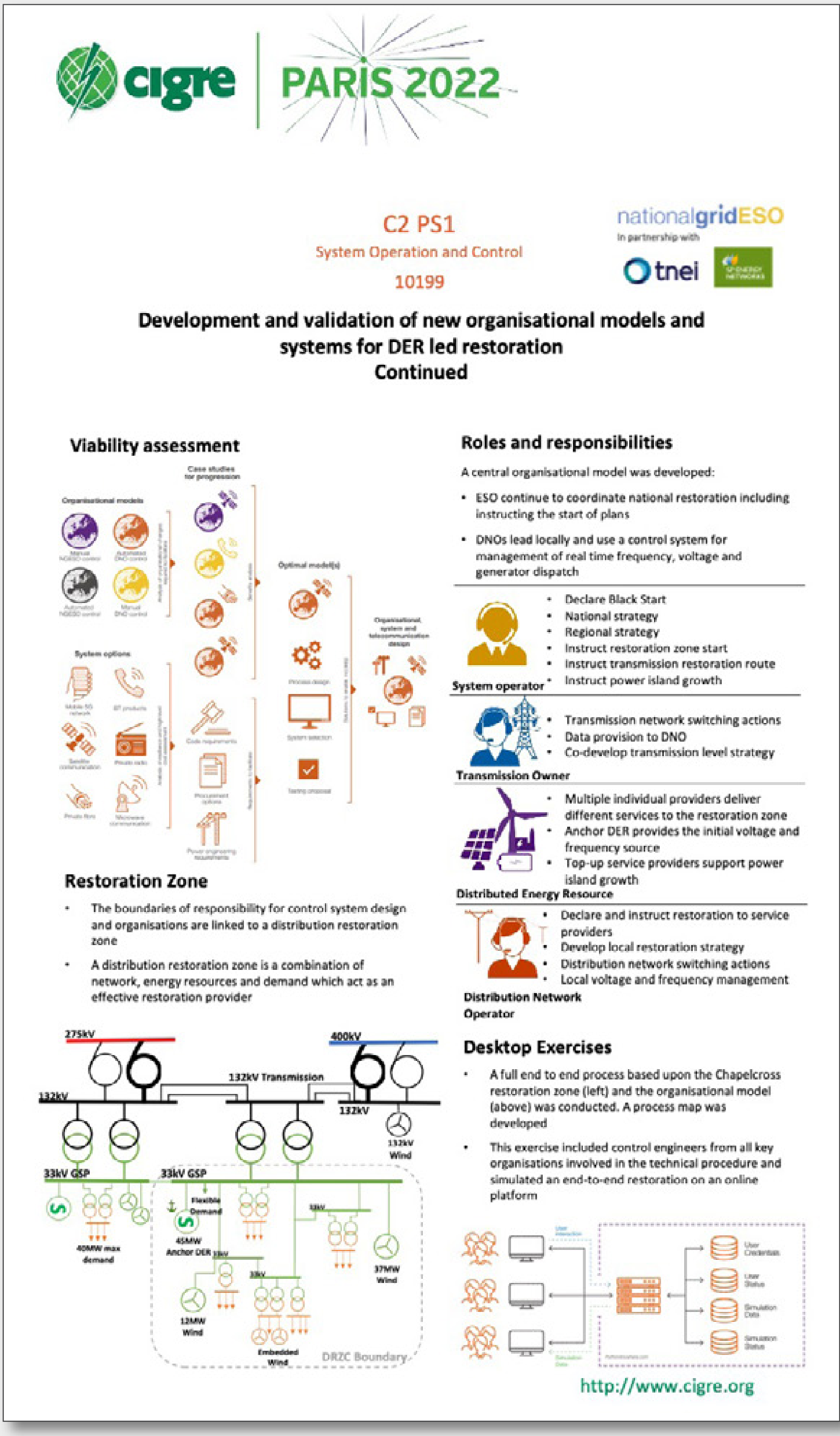
Discussion

- Organisational change will be needed to facilitate distributed restoration
- Local voltage and frequency management by distribution system operators is a very significant change but was accepted by all stakeholders
- No blockers were identified but multiple improvements were captured and incorporated into the final design.
- An online, interactive platform emulating control systems led to very high-quality improvements being identified and confidence in the processes developed
- Learnings from this development exercise can be applied to in-service training
- Engaging multiple vendors for an initial control system functional specification promoted competition, allowed for exploration of various conceptual design principles and led to overall improvements in the prototype build

Conclusion

- A working model for distribution level restoration has been developed and is being procured in GB as part of ongoing regional tenders
- Significant organizational, control system and power systems changes are needed to facilitate restoration from DER
- Changes identified and implemented from desktop exercises enabled significant refinement and development of the final organizational design
- Whilst these changes incur costs, the benefits of enhanced competition, decarbonisation and future proofing of an essential system capability leads to a net consumer benefit of between £86m and £144m
- Power engineering, control system and organizational challenges continue to exist in the models developed but ongoing training, assurance testing and infrastructure build will continuously refine the specifications

http://www.cigre.org



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Development and validation of new organisational models and systems for DER led restoration
Continued

Viability assessment

Restoration Zone

- The boundaries of responsibility for control system design and organisations are linked to a distribution restoration zone
- A distribution restoration zone is a combination of network, energy resources and demand which act as an effective restoration provider

Roles and responsibilities

A central organisational model was developed:

- ESO continue to coordinate national restoration including instructing the start of plans
- DNOs lead locally and use a control system for management of real time frequency, voltage and generator dispatch

System operator
- Declare Black Start
- National strategy
- Regional strategy
- Instruct restoration zone start
- Instruct transmission restoration route
- Instruct power island growth

Transmission Owner
- Transmission network switching actions
- Data provision to DNO
- Co-develop transmission level strategy

Distributed Energy Resource
- Multiple individual providers deliver different services to the restoration zone
- Anchor DER provides the initial voltage and frequency source
- Top-up service providers support power island growth

Distribution Network Operator
- Declare and instruct restoration to service providers
- Develop local restoration strategy
- Distribution network switching actions
- Local voltage and frequency management

Desktop Exercises

- A full end to end process based upon the Chapelcross restoration zone (left) and the organisational model (above) was conducted. A process map was developed
- This exercise included control engineers from all key organisations involved in the technical procedure and simulated an end-to-end restoration on an online platform

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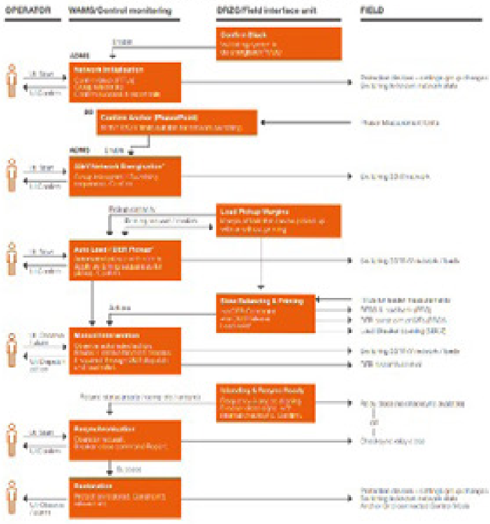
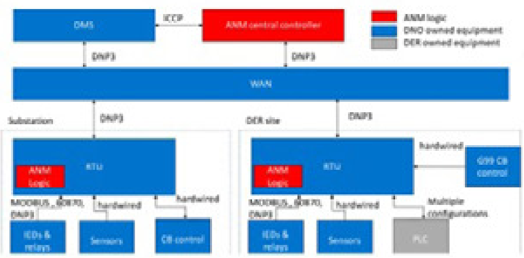
Continued

Restoration Zone Control System

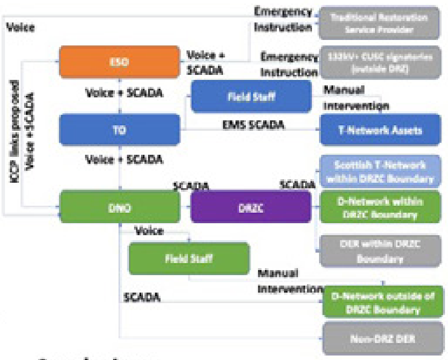
- Four different vendors were engaged to develop front end engineering designs for a control system
- A single vendor was then selected to build a prototype. The key functions and interactions with this selected design are detailed below
- Fast balancing functions maintain network stability through sub second control enhancing block load pickup capability of energy resources
- Slow balancing maintains appropriate energy distribution across the restoration process



- The communications and control architecture that facilitates these processes is summarized in the graphic below



Telecommunications interface map



Conclusions

A working model for distribution level restoration has been developed and is undergoing procurement in GB

- Cost benefit analysis has demonstrated expected consumer benefit of between £86m and £144m
- However, this model increases the complexity of restoration and leads to the following significant change requirements:

System operator

- Inter control centre protocol required for visibility between the DNOs and System Operator.
- Enhanced training requirements

Transmission Owner

- Phasor Measurement Units and data exchange with DNO to facilitate synchronisation
- Additional network synchronising points

Distributed Energy Resource

- New power resilience and communications specification
- Technical changes to deliver contracted service
- Robust training and minimum staffing requirements

Distribution Network Operator

- Restoration control system implementation
- New power resilience and communications requirements
- Significantly enhanced training requirements
- Potential additional staff requirements

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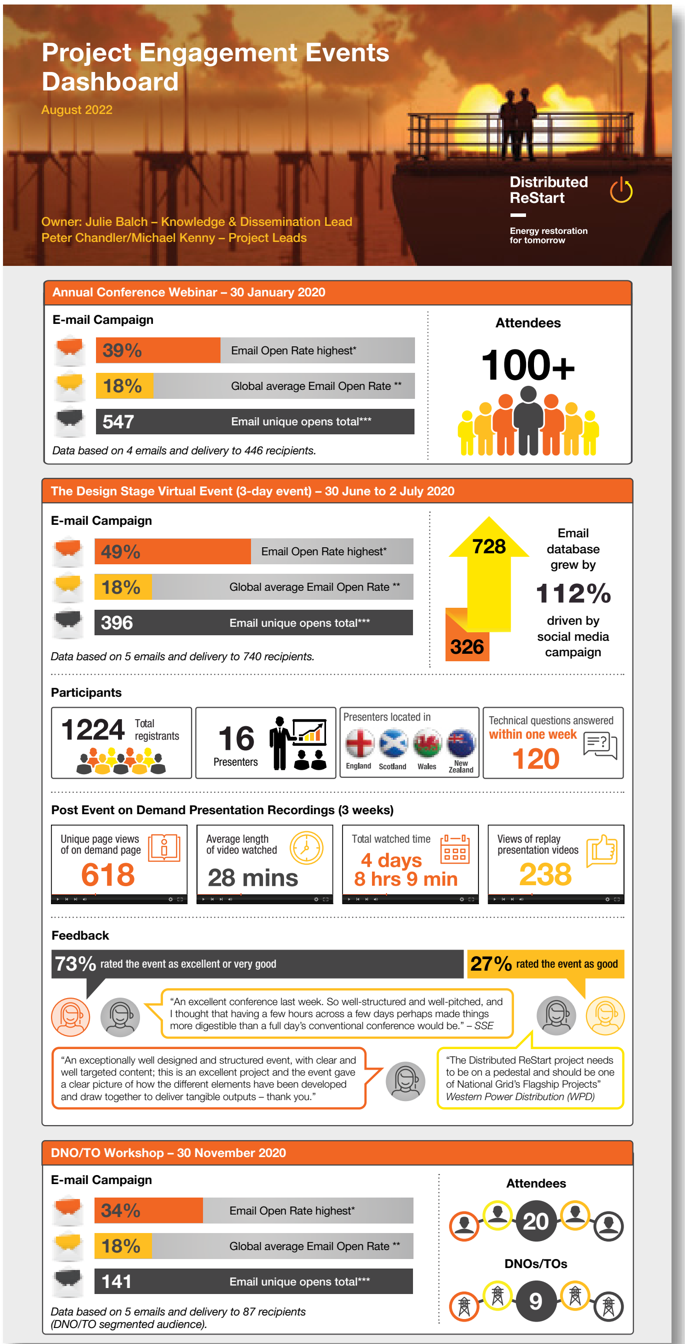
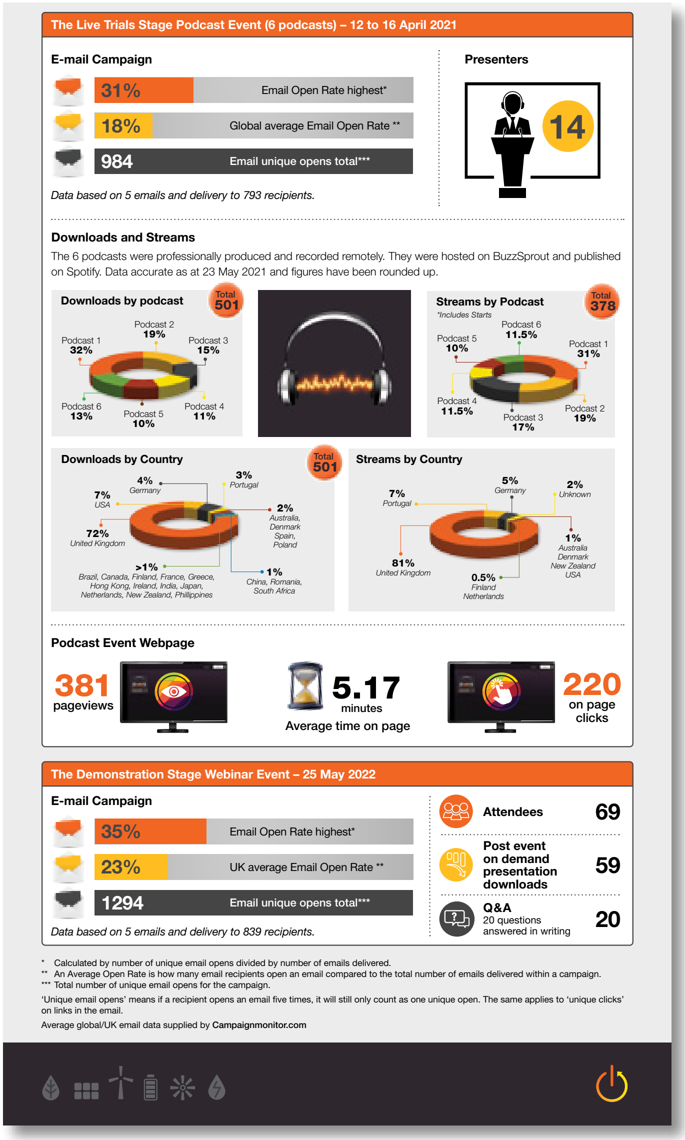
Appendix 3: Stakeholder Engagement Dashboards





Organisational, Systems & Telecoms (OST) Workstream

Stakeholder Engagement Dashboard

July 2022

Owner: Julie Balch - Knowledge & Dissemination Lead
Christopher Salter - OST Lead
Dozien Nnabuife - OST Specialist

Distributed ReStart
Energy restoration for tomorrow

OST Desktop Exercises – Process Design – 27 May/8 June/6 July 2022

E-mail Campaign

23%	Email Open Rate highest*
18%	Global average Email Open Rate **
568	Email unique opens total***

Data based on 3 emails and delivery to 801 recipients.

Participants
Desktop Exercises:

	DER	DNO	ESO/TO
27 MAY:	6	4	4
8 JUNE:	11	11	8
6 JULY:	31	7	11

Participants
Observers:

OBSERVERS
27 MAY: 22
8 JUNE: 17
6 JULY: 15

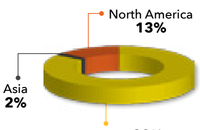
OST Final Report Podcast – 30 September 2021

E-mail Campaign

25%	Email Open Rate highest*
18%	Global average Email Open Rate **
891	Email unique opens total***

Data based on 5 emails and delivery to 793 recipients.

Downloads by Country



Final Report Podcast

The 50-minute podcast was professionally produced and recorded remotely. The podcast was hosted on BuzzSprout and published on Spotify on 30 September 2001. Data accurate as of 31 October 2021.

Targeted audience segment: Distribution Network Operators (DNOs) and Transmission Owners (Tos)

Downloads/streaming by segmented audience

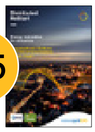
85%

Reports Downloads

Organisational, Systems and Telecommunications Viability Report
November 2019

197

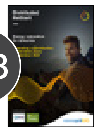

Organisational, Systems and Telecommunications Design Stage I
October 2020

125


Organisational, Systems and Telecommunications Design Stage II
December 2020

174


Operating a Distribution Restoration Zone (final report)
September 2021

168


* Calculated by number of unique email opens divided by number of emails delivered.
** An Average Open Rate is how many email recipients open an email compared to the total number of emails delivered within a campaign.
***Total number of unique email opens for the campaign.
'Unique email opens' means if a recipient opens an email five times, it will still only count as one unique open. The same applies to 'unique clicks' on links in the email.
Global average email data supplied by **Campaignmonitor.com**

Procurement & Compliance (P&C) Workstream

Stakeholder Engagement Dashboard

July 2022

Owner: Julie Balch – Knowledge & Dissemination Lead
Roop Phull – Procurement & Compliance Lead
Hannah Rochford – Commercial Lead

Distributed ReStart

Energy restoration for tomorrow

Stakeholder Event (webinar) – 20 May 2021

E-mail Campaign

24%	Email Open Rate highest*
18%	Global average Email Open Rate **
736	Email unique opens total***

Data based on 4 emails and delivery to 785–790 recipients.

Webinar Attendees 35

Organisations Attended 29

Test Procurement Event – 28 July to 3 September 2021

E-mail Campaign

39%	Email Open Rate highest*
18%	Global average Email Open Rate **
962	Email unique opens total***

Data based on 5 emails and delivery to 733–796 recipients.

Webinar Launch 28 July

Webinar Attendees 13

Completed mock tenders 5

Five organisations submitted completed mock tenders.

Final Report Podcast Event – 21 January 2022

E-mail Campaign

27%	Email Open Rate highest*
21.5%	Global average Email Open Rate **
582	Email unique opens total***

Data based on 4 emails and delivery to 822 recipients.

Final Report Podcast

The podcast was professionally produced and recorded remotely. It was hosted on Buzzsprout and published on Spotify.

72 **Downloads and Streams**

Data accurate as of 18 May 2021.

Stakeholder Meetings

Stakeholder 1–1 Meetings

10 DERs

6 DNOs

Reports Downloads

Functional Requirements for Procurement & Compliance *November 2019*	126
A high-level outline of commercial and regulatory arrangements – *October 2020*	128
Distribution Restoration future commercial structure and industry codes recommendations (final report) – *December 2021*	135

* Calculated by number of unique email opens divided by number of emails delivered.
** An Average Open Rate is how many email recipients open an email compared to the total number of emails delivered within a campaign.
*** Total number of unique email opens for the campaign.

'Unique email opens' means if a recipient opens an email five times, it will still only count as one unique open. The same applies to 'unique clicks' on links in the email.

Global average email data supplied by **Campaignmonitor.com**

Power Engineering and Trials (PET) Workstream

Stakeholder Engagement Dashboard

September 2022

Owner: Julie Balch - Knowledge & Dissemination Lead
Neil Miller - PET Workstream Lead (Galloway & Chapelcross)
Jack Haynes - PET Workstream Lead (Redhouse)

Distributed ReStart
Energy restoration for tomorrow

Case Study (Live Trials) Selection Process – March 2019

DER questionnaire uptake: 30%

DERs engaged: 60

Report: Assessment of Power Engineering – Aspects of Black Start from DER Part 1 – July 2020

E-mail communication

35%	Email Open Rate*
18%	Global average Email Open Rate **
251	Email unique opens total***

Data based on 1 email and delivery to 723 recipients.

Report downloads: 320

Report: Assessment of Power Engineering – Aspects of Black Start from DER Part 2 – December 2020

E-mail communication

31.6%	Email Open Rate*
18%	Global average Email Open Rate **
280	Email unique opens total***

Data based on 1 email and delivery to 753 recipients.

Report downloads: 264

Report: Demonstration of Black Start from DERs (Live Trials Report) Part 1 – December 2021

E-mail campaign

31.61%	Email Open Rate*
18%	Global average Email Open Rate **
280	Email unique opens total***

Data based on 1 email and delivery to 753 recipients.

Report downloads: 202

Live Trial Galloway Email Comms – May 2022

E-mail campaign

31.4%	Email Open Rate*
23%	Global average Email Open Rate **
287	Email unique opens total***

Data based on 1 email and delivery to 837 recipients.

Live Trial Chapelcross Email Comms – July 2022

E-mail campaign

32.1%	Email Open Rate*
23%	Global average Email Open Rate **
290	Email unique opens total***

Data based on 1 email and delivery to 853 recipients.

Report: Demonstration of Black Start from DERs (Live Trials Report) Part 2 – October 2022

E-mail communication

31.84%	Email Open Rate*
23%	Global average Email Open Rate **
360	Email unique opens total***

Data based on 1 email and delivery to 848 recipients.

Report downloads: 88

* Calculated by number of unique email opens divided by number of emails delivered.
** An Average Open Rate is how many email recipients open an email compared to the total number of emails delivered within a campaign.
*** Total number of unique email opens for the campaign.
'Unique email opens' means if a recipient opens an email five times, it will still only count as one unique open. The same applies to 'unique clicks' on links in the email.
Global average email data supplied by **Campaignmonitor.com**

Closedown Event Dashboard

30 November 2022

Owner: Julie Balch - Knowledge & Dissemination Lead
Peter Chandler/Michael Kenny - Project Leads

Distributed ReStart
Energy restoration for tomorrow

Email Campaign

Teaser, registration and on-demand emails

34%	Email Open Rate highest *
23%	UK Average Open Rate **
203	Unique Clicks total ***
1,439	Unique opens total ****

Data based on 5 emails and delivery to 869 recipients.

Closedown Event Webinar

72 Attendees

9 Presenters

8 Post event on demand presentation downloads.

Final Findings and Proposals Report

The Closedown Event covered the project's final findings and proposals, and the report was promoted in the Closedown Event email campaign.

Downloads 45

Closedown Report

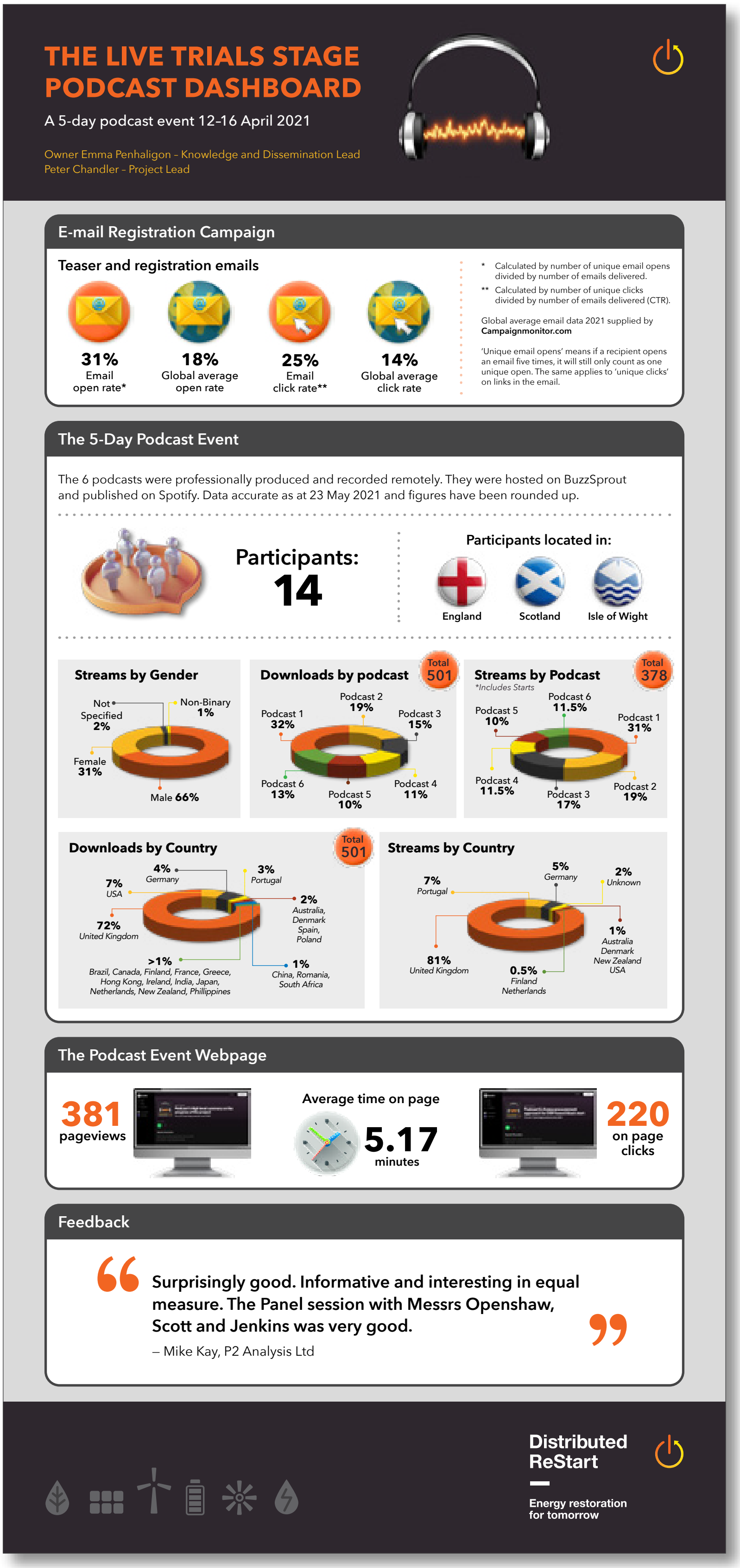
This report is due to be published in February 2023 and engagement statistics will be provided after the launch.

February 2023

* Email Open Rate is the percentage of subscribers who open an email out of your total number of subscribers.
** An Average Open Rate is how many email recipients open an email compared to the total number of emails delivered within a campaign.
*** Unique Clicks is the measure of how many people clicked on a hyperlink, CTA, or image within a particular email. It only measures the first click, it does not count if the link is clicked multiple times.
**** Total number of unique email opens for the campaign. Unique Opens means if a recipient opens an email five times, it will still only count as one unique open.

Average UK email data supplied by **Campaignmonitor.com**

Appendix 4: The Live Trials Stage Podcast Dashboard



Appendix 5 – Updated CBA Assumptions

Below we describe the updates that have been made for the 2022 Closedown Report. In addition to these changes, we have also made some small refinements to the overall logic of the CBA model.

De-Rating of Variable Generation

We have reverted to using the original de-rating factors for variable generation, following discussion about how distributed and variable generation would practically contribute to restoration. This means we are using derating factors for variable generation which reflect their typical output, rather a more onerous worst case. The rationale is that restoration is unlikely to solely rely on variable generation – if it was, then the worst-case derating factors (which were derived from the Capacity Market) may be more inappropriate. Instead, variable generation will be supporting restoration alongside other types of dispatchable generation.

Base Service Costs

We have updated the base cost of the service (e.g. excluding costs related to readiness and retrofit equipment), to reflect recent ESO experience of restoration costs paid to each provider. This cost has increased by ~20% compared to the original CBA.

Costs of Readiness

The original 2018 CBA included inputs that captured the costs involved in making large thermal generators available. To be available to start up quickly, these generators need to be kept in a state of readiness, which means ensuring they are dispatched regularly (e.g. once every month or every week). This may require ESO to act in the balancing market to dispatch these generators, if the market would not require them to run, but if they are going to provide restoration services.

We have updated and simplified the way the model approximates these costs, which allows for them to be scaled relative to each individual future energy scenario. This means we can account for, for example, the more frequent or less frequent dispatch of transmission connected gas generation in different scenarios, and the different assumptions about fuel prices.

Choice of Central Scenario

The previous iterations of the CBA used the least transformative of the four Future Energy Scenarios (FES) , which in the 2017 FES (used in the original submission) was known as Slow Progression and, in the 2020 update, was renamed to Steady Progression.

The outlook for the development of the energy system has changed substantially since 2017. Most significantly, legislation requiring achievement of net-zero greenhouse gas emissions was passed in 2019. This is reflected in some of the 2020 FES, but not Steady Progression. In fact, in the most recent FES, the least transformative scenario has now been renamed to Falling Short, to reflect that it does not achieve this crucial goal.

We have therefore decided to use the most transformative scenario, Leading the Way, as our baseline for the CBA, as this scenario will require the most significant changes in how ESO operates the system, including its approaches to restoration.

We have continued to use the 2020 FES to minimise the changes between iterations of the CBA.

Appendix 6: Abbreviations and Acronyms

ADMS	advanced distribution management system
AG	anchor generator
ANM	active network management (system)
BAU	business as usual
BEIS	Department for Business, Energy & Industrial Strategy
BESS	battery energy storage system
BLPU	block load pickup
BSP	bulk supply point
BSUoS	balancing services use of system
CBA	cost-benefit analysis
CCGT	combined cycle gas turbine
CHP	combined heat and power
CIGRE	Conseil International des Grands Réseaux Electriques; this translates as Council on Large Electric Systems
CUSC	Connection and Use of System Code
DER	distributed energy resources
DERMS	distributed energy resources management systems
DMS	distribution management system
DNOs	distribution network operators
DOL	direct online (energisation)
DRZ	distribution restoration zone
DRZC	Distribution Restoration Zone Controller
DRZP	Distribution Restoration Zone Plan
DSO	distribution system operator
DSR	demand side response
EIS	Energy Innovation Summit
EMS	energy management system
ENA	Energy Networks Association
ENIC	Electricity Networks Innovation Conference
ENSTG	Energy Networks Strategic Telecommunications Group
ESO	electricity system operator
ESR	electricity system restoration
ESRS	Electricity System Restoration Standard
EU	European Union
EV	electric vehicle
FAT	factory acceptance testing
FES	Future Energy Scenarios
GFC	grid-forming converter
GSP	grid supply point
HiL	hardware-in the-loop (testing)
ICCP	Inter-Control Centre Communications Protocol
I&C	industrial and commercial
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
K&D	Knowledge and Dissemination workstream

kW	kilo watt
MCR	Material Change Request (NIC requirement)
MVA	mega volt ampere
MVAr	mega volt ampere of reactive power
MW	mega watt
NETS	national electricity transmission system
NIA	Network Innovation Allowance
NPV	net present value
NREL	The National Renewable Energy Laboratory (in the United States)
OEM	original equipment manufacturer
OPTEL	operational telephony network
OST	Organisational, Systems and Telecommunications workstream
PAs	participation agreements
P&C	Procurement and Compliance workstream
PET	Power Engineering and Trials workstream
PHiL	power hardware-in-the-loop
PMO	Project Management Office
PNDC	Power Networks Demonstration Centre
PoW	point on wave
PPR	project progress report
PV	(solar) photovoltaic
Q&A	questions and answers
RaaS	Resilience as a Service
RC	resistor-capacitor
RDPs	Regional Development Programmes
RIIO-ED2	Revenue = Incentives + Innovation + Outputs - Electricity Distribution 2. The next price control (known as RIIO-ED2) will cover the five-year period from 1 April 2023 to 31 March 2028.
RTDS	real time digital simulator
RTU	remote terminal unit
SAP	Stakeholder Advisory Panel
SE	South East
SGRE	Siemens Gamesa Renewable Energy
SG	synchronous generator
SGT	super-grid transformer
SPEN	Scottish Power Energy Networks
SPD	Scottish Power Distribution
SPR	Scottish Power Renewables
SPT	Scottish Power Transmission
SSEN	Scottish & Southern Electricity Networks
STATCOM	static synchronous compensator
STC	System Operator Transmission Owner Code
SVC	Static VAR compensator
TAC	Technology Advisory Council
TO	transmission owner
TOV	temporary overvoltages
TRL	technology readiness level
TRV	transient recovery voltage
TUS/TuS	top-up service (provider)
VAr	volt amperes reactive
VCOC	voltage-controlled overcurrent
VSM	virtual synchronous machine
VT	voltage transformer

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