Distributed ReStart

Energy restoration for tomorrow

Organisational, systems and telecommunications viability report

In partnership with:

Contents

Abstract

The Distributed ReStart project (formerly known as Black Start from DER) is a partnership between National Grid Electricity System Operator (ESO), SPEN and TNEI (a specialist energy consultancy) that has been awarded £10.3 million of Network Innovation Competition (NIC) funding.

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

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

Project description

The project is made up of five workstreams. The Project Direction and Knowledge Dissemination workstreams cover the effective management of the project and sharing of learning. The other three workstreams cover the wide range of issues to enable Black Start services from DER:

- The Organisational Systems & Telecommunications (OST) workstream is considering the DER-based restoration process in terms of the different roles, responsibilities and relationships needed across the industry to implement at scale. It will specify the requirements for information systems and telecommunications, recognising the need for resilience and the challenges of coordinating Black Start across a large number of parties. Proposed processes and working methods will be tested later in the project in desktop exercises involving a range of stakeholders.
- The Power Engineering & Trials (PET) workstream is concerned with assessing the capability of GB distribution networks and installed DER to deliver an effective restoration service. It will identify the technical requirements that should apply on an enduring basis. This will be done through detailed analysis of the case studies and progression through multiple phases of review and testing to achieve demonstration of the Black Start from DER concept in 'live trials' on SPEN networks. Initial activities have focused on reviewing technical aspects of DER-based restoration in a number of case study locations that will support detailed analysis and testing within the project. Each case study is built around an 'anchor' resource with 'grid forming' capability, i.e. the ability to establish an independent voltage source and then energise parts of the network and other resources. Then it is intended that other types of DER, including batteries if available, join and help grow the Power Island, contributing to voltage and frequency control. The ultimate goal is to establish a Power Island with sufficient capability to re-energise parts of the transmission network and thereby accelerate wider system restoration.
- The Procurement & Compliance (P&C) workstream will address the best way to deliver the concept for customers. It will explore the options and trade-offs between competitive procurement solutions and mandated elements. It will make recommendations on the procurement strategy aiming to be as open and transparent as possible while reflecting wider industry discussions on related topics like Whole System Planning and the development of distribution system operator (DSO) functions. It will feed into business as usual activities to make changes as necessary in codes and regulations.

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

Executive summary

This report is the first deliverable from the Organisational, Systems and Telecommunications (OST) workstream within the Distributed ReStart project. It outlines capabilities of existing Black Start participants and explores organisational structures and skill sets, together with resilience and capability of Operational Telecommunications. By applying these parameters to differing models of high-level generic organisational structures we present a variety of pathways to deliver a Distributed ReStart solution.

Our focus to date has been to identify the main challenges to the delivery of Distributed ReStart, and consider a range of options to address these challenges. At this stage, our aim is to present a wide variety of options. We are not proposing any solutions.

As we move into the design of future processes, roles, and Operational Telecommunications, we will refine our analysis, considering any industry-related developments, initiatives or requirements to develop a set of proposals to deliver a least regrets solution.

Within this report, we demonstrate the importance of stakeholder engagement before describing the general methodology, challenges and assumptions. This is followed by a review of organisational structures and skills, a high-level analysis of Operational Telecommunications and, finally, an outline of our conclusions to date and planned next steps.

Challenges

Black Start stakeholders

Under traditional Black Start processes, a limited number of stakeholders are actively involved; NGESO, TOs, DNOs and a relatively small number of Black Start service providers, mostly large, transmission-connected power stations. These processes and stakeholders are generally well established. Alongside this, current Operational Telecommunications (voice and data) use dedicated fibre links ensuring:

- robust, resilient Operational Telecommunications with a low cyber risk
- GB wide secure, reliable data and voice network for day-to-day operational management and Black Start operation of the network.

The introduction of DER into a Black Start process provides a significant challenge to OST including (but not limited to):

- the volume and types of stakeholders, which could both increase considerably;
- the DNOs are likely to be performing new DSO functions. However, how the DSO functions will be realised/performed is still uncertain; and
- there may be a reliance on other parties including aggregators and generator control centres remote from the resources themselves.

The increase in stakeholder numbers and the variety of stakeholder types are significant challenges to the OST workstream in developing Black Start processes. They may lead to a vast increase in the number of data points, and the number and type of potential Operational Telecommunications that could be used (e.g. microwave, satellite), which itself represents an increased risk in terms of ensuring cyber security and end-to-end power resilience.

Changing environment

Both the energy and telecommunication industries are undergoing periods of rapid change. We are monitoring known projects and initiatives to identify:

- where we can gain useful learning; and
- where we need to feed into developments.

Alongside specific initiatives, we are working closely with a wide range of stakeholders to ensure we keep abreast of:

- any new developments that have a sufficient technology readiness level (TRL) to be considered; and
- Black Start participants' current and planned business models.

Telecommunications resilience

Whilst a focus is frequently placed on power resilience, it is essential that we consider resilience as a whole, including both cyber and physical security aspects.

As mentioned above, the current Black Start process utilises a relatively low number of large, well established players using dedicated fibre links between parties with long-standing resilience requirements. Inclusion of DER in the process means significant change across all areas of resilience, including:

- what resilience is required;
- what resilience is technically and economically achievable;
- how we gain assurance that the required resilience is provided.

Method

Our approach has been to consider:

- how the current Black Start process works;
- the key requirements for a Black Start process;
- the challenges of incorporating DER into the process;
- what future-proofing is needed; and
- what options are available to fulfil these requirements.

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

Engagement

Black Start participants

Significant investment has been made in gathering views from DNOs and TOs due to their pivotal role in any future Black Start process. We will continue to engage with these parties through our Stakeholder Advisory Panel, workshops, bilateral meetings, industry groups and other project initiatives.

For example, on 12 September the project hosted an event inviting DNOs and TOs to share their views on the future of restoration. This event focused on confirming 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. The outputs of the workshop are captured in a document published on the project website: **https://www.nationalgrideso.com/document/153861/download**

In terms of gathering information from DER, the principal approach to date has been through questionnaires and via discussions with potential participants in the live trials. Further detailed discussions with DER are an important next step.

Wider industry

Energy Networks Strategic Telecommunications Group (ENSTG)

Since July 2019 we have been attending the ENSTG. This group is facilitated by the ENA and provides a focus for discussion and coordination of its DNO, TO and SO members and the Joint Radio Company (JRC) to identify and share how Operational Telecommunications are transforming and what enhanced capability is needed to address current and future challenges.

Through sharing our thinking on Operational Telecommunications options with the ENSTG, we have gained valuable feedback, informing our next steps and re-emphasising the variety of telecommunications solutions, hence our 'no one size fits all' approach.

OFCOM

We have had fruitful discussions with OFCOM, initially via the ENSTG and subsequently through bilateral dialogue. To date, our discussions have focused on ensuring that we are considering all viable options for Operational Telecommunications and that our initial review is credible.

JRC

We have gained valuable feedback from JRC bilaterally, via the ENSTG, and at their annual conference themed 'The UK Smart Grid Vision' (11 September 2019) **https://www.jrc.co.uk/conferences/2019**

Suppliers, manufacturers and service providers

Distributed ReStart is engaged with several leading suppliers to gather and develop design requirements for systems to support inclusion of DER in Black Start, and to assess potential technology and solutions available to deliver cost effective power resilient Operational Telecommunications. Further industry-wide engagement will continue.

Existing Black Start service providers

OST has met with a number of conventional service providers. Of particular note is our participation in Local Joint Restoration Plan (LJRP) reviews and workshops.

Engagement with projects/initiatives

In such a dynamic world, engagement and knowledge sharing with other projects and initiatives, such as the ENA Open Networks, introduction of a Black Start Standard and distributed generation Cybersecurity Connection Guidance anticipated from BEIS, is vital for OST to develop appropriate solutions.

Organisational analysis

The role of control staff and the nature and volume of their work can change significantly from normal operations to that during a restoration process. Through workshops and bilateral meetings with NGESO, TOs, DNOs and some DER, we have sought to develop a baseline capability of organisations during this distressed operating scenario from which we can compare potential options for organising a Distributed ReStart.

A set of models have been developed to illustrate possible stakeholder roles in facilitating a Distributed ReStart. These represent discrete options for control of a Black Start and levels of automation. These models will enable the project to understand possible change requirements whilst remaining flexible to meet the Distribution System Operator (DSO) worlds being developed through the ENA Open Networks project and wider industry changes. These models will be developed and refined in the next phase of work to define processes and the stakeholder responsibilities.

Whilst we are not yet in a position to propose any specific solutions, we have started to identify the benefits, difficulties and risks of alternative organisational options.

Our next steps will take this analysis further to develop a detailed process map with clear demarcation of potential process ownership, together with the associated roles and training requirements. Where appropriate, we will compare the benefits of manual processes versus the use of additional supporting tools or automation. Our comparison will include consideration of faster, more accurate or efficient restoration.

A significant part of the demonstration phase will be the use of desktop exercises to develop processes and suitable use of automation for each model. We hope to trial some or all of these options within the live trials in the PET workstream. For the latest PET workstream report please see: **https://www.nationalgrideso.com/document/149961/download**

Operational Telecommunications

The existing Black Start process requires an open voice communication channel between the applicable parties and visualisation of network status and operating condition via the ESO's Integrated Energy Management System (IEMS).

Of particular note is the current National Grid Operational Telecommunication (OpTel) Network, which is the designated network for traditional Black Start communication. OpTel carries data, including control telephony, SCADA and protection to support the operations of National Grid control centres and various sites (including DNOs and Black Start service providers). This OpTel network is Black Start power resilient – the communication path to support the Black Start process being fully backed up by a combination of battery and diesel back-up supply.

The main systems used are currently:

- NGESO: IEMS (Integrated Energy Management System)
- DNOs: DMS (distributed management system), a distribution equivalent to NGESO's IEMS systems
- ICCP: (Inter-Control Centre Communications Protocol) this is a data sharing protocol allowing the two systems above to exchange data automatically.

Any proposed telecommunication infrastructure would be required to support the end-to-end voice and data communications necessary to facilitate the Black Start participants in restarting the power system safely and efficiently.

The assessment of Operational Telecommunications has included a review of existing voice and data communication infrastructure; the technologies currently in place; the systems used; and an initial review of cyber security.

Distributed ReStart is now exploring various options for delivering the telecommunications capability to enable Black Start from DER. We are considering options for extending the current infrastructure to DER, and options to provide a totally new network. Technologies being evaluated include those that are ready to be deployed immediately or on completion of the Distributed ReStart project in 2022. Our review to date has been high-level and we will continue to evaluate the options and discuss their costs, benefits and risks with current and potential Black Start participants.

Summary of conclusions

Our analysis to date has allowed us to identify:

- typical capabilities of current Black Start participants;
- a high-level generic process to deliver Distributed ReStart;
- which models to take forward for further analysis; and
- the broad requirements and options for future Operational Telecommunications.

Through these findings, we have concluded that there are no OST blockers to delivering Distributed ReStart. However, in addition to the standard approach to development of processes and procedures (i.e. one of simplicity and clarity), there are some important requirements to include in the design phase:

- Familiarity: Black Start responsibilities, interfaces and systems should align closely with BAU operations whenever possible.
- Resilience: End-to-end Operational Telecommunications resilience is required (including power resilience and resistance to cyber or physical attack).
- Flexibility: There is unlikely to be a 'one size fits all' solution.

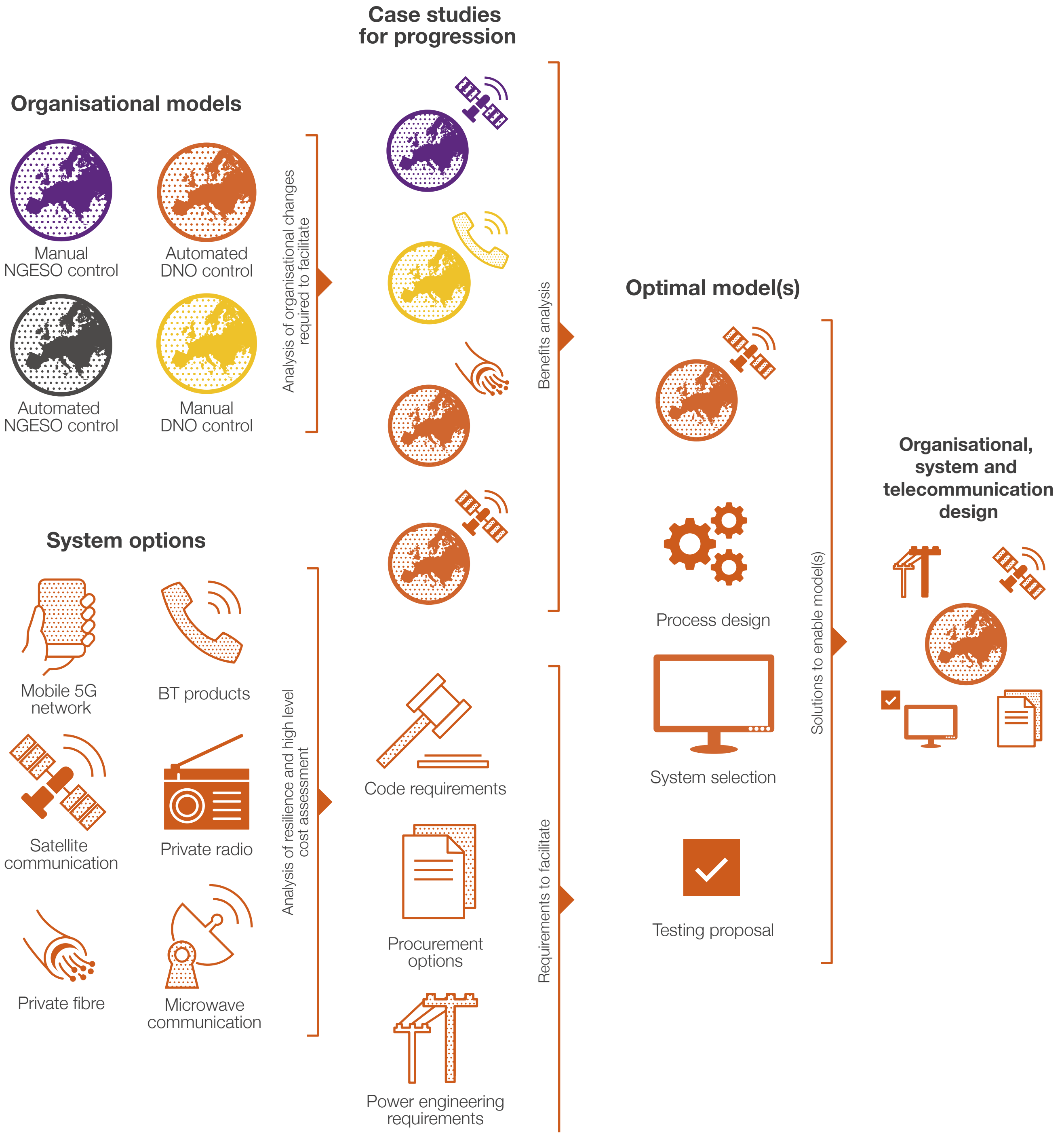
Next steps

As we progress through the next stages of the project, we expect some options may be parked and others taken forward. We do not expect to recommend a single option (either organisational or Operational Telecommunications), but instead anticipate a combination of options will meet the project and stakeholder needs.

Cost and viability analysis will be applied to a range of case studies across our models. Working closely with the Power Engineering and Trials (PET) and Procurement and Compliance (P&C) workstreams, we will thus define process and specification, ultimately delivering a coherent design; this iterative process is represented below in figure 0.1.

Figure 0.1

Depiction of the overall process for the organisational systems and telecommunications design. Note that any indication of solutions is for illustrative purposes only at this stage



Introduction

1. Introduction

1.1 This report

Our focus throughout has been to identify the main challenges that will require addressing to deliver Distributed ReStart and, at a high level, consider a wide range of options to meet these challenges. Although not exhaustive, for completeness, we have chosen to present all widely known options. At this stage, we are not proposing any solutions.

As we move into the design of future processes, roles, and Operational Telecommunications, we will refine our analysis, considering other initiatives and requirements to develop a set of proposals to deliver a least regrets solution.

The general methodology for each area (organisational and Operational Telecommunications) is described in section 5 'General approach'. In summary, our approach has been to consider:

- how the current Black Start process works;
- the key requirements for a Black Start process;
- the challenges of incorporating DER into the process;
- what future-proofing is needed; and
- what options are available to fulfil these requirements.

To present a broad spectrum of options, we have reviewed both existing capabilities and the capabilities of technologies available in the near future. During this process, we have actively sought challenge from stakeholders across the industry, including Black Start participants, OFCOM and the STG (Strategic Telecommunications Group) (described in section 4 'Industry engagement').

Subsequent cost and viability analysis will allow us to define processes and specifications for a range of case studies. We will work closely with the other workstreams; and with external stakeholders to produce an overall coherent design. The diagram in figure 1.1 represents this iterative process and key deliverables for the workstream.

In the organisational analysis (sections 7 to 10), we review the current methods used to facilitate the existing Black Start process and present a number of models to illustrate the impact of a range of options.

In sections 11 to 16, Operational Telecommunications, we examine the resilience provided by the current voice and data infrastructure and the technologies used; present a summary of the future options high-level assessment; illustrate our findings using two Distributed ReStart case studies; and provide a summary of our current thinking on cyber security.

Finally, in section 16, we present our initial conclusions and, in section 17, our proposed next steps, describing how we will take this work forward into the next phase and complete OST Project Deliverable 2 by 2 October 2020 **https://www.nationalgrideso.com/document/140741/download**

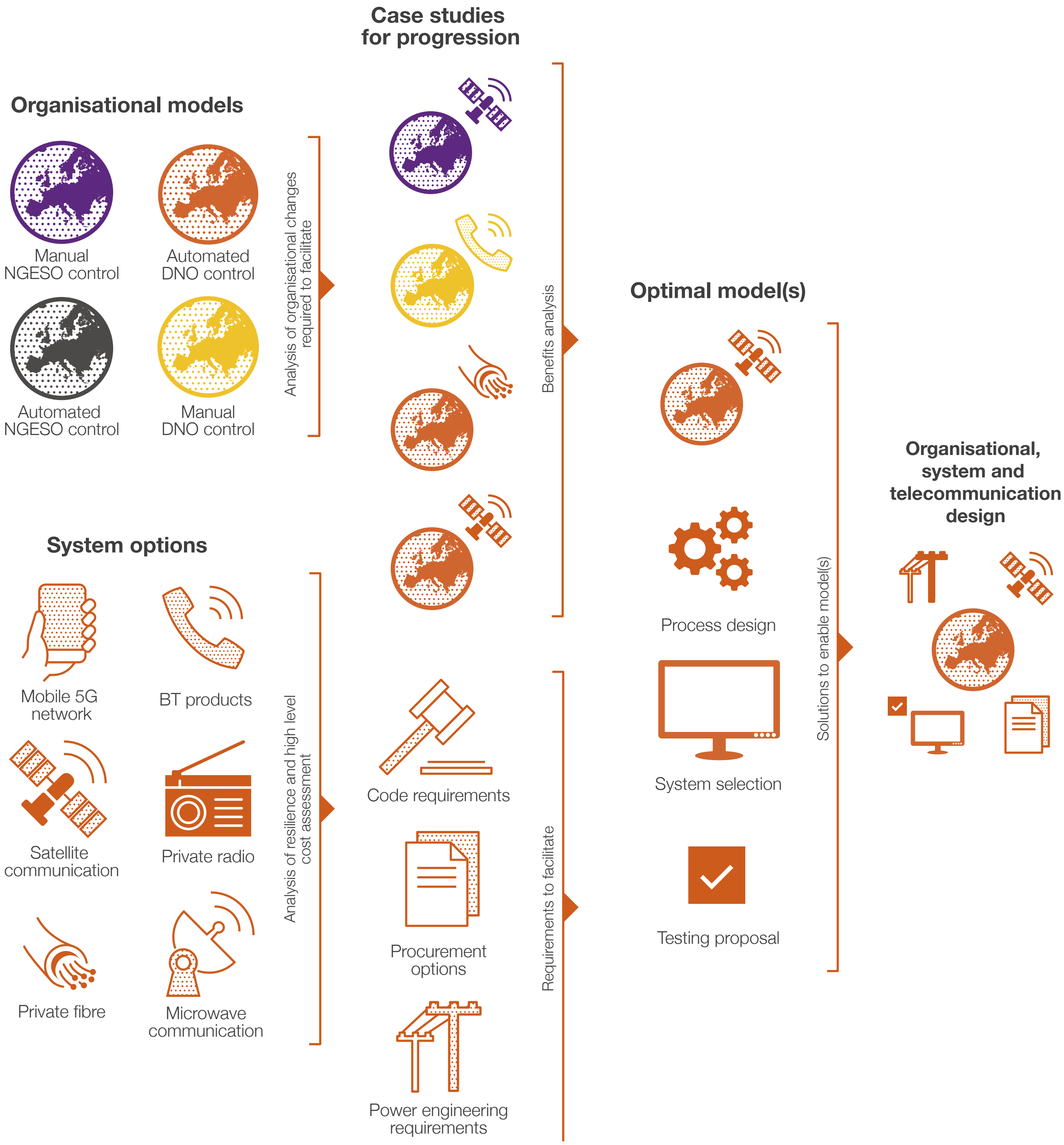
This will comprise of a proposal for how the Black Start from DER will operate as a process. To include:

- 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.

Annexes follow from section 18.

Before looking at the details, it is important to consider the backdrop to the project and the importance placed on extensive stakeholder engagement, as summarised in section 4. There are also a number of key challenges for this workstream and the project in general, described in the following section.

Figure 1.1
The high-level process of the project (any indication of outcomes at later stages is purely illustrative to demonstrate the process we will apply).



2. Key challenges

Across all OST activities, significant initiatives and changes are either underway or planned during the project duration. Some changes are as a direct result of the project, but many are happening in parallel with Distributed ReStart and provide us with several challenges to overcome.

2.1 Black Start stakeholders:

We currently have a limited number of stakeholders actively involved in the Black Start process: NGESO, TOs, DNOs and a relatively small number of Black Start service providers mostly large, transmission-connected power stations. These stakeholders and the Black Start process are well established and the control engineers are trained to maintain Black Start capability 24/7, 365 days a year.

Between these stakeholders, current Operational Telecommunications (voice and data) use dedicated fibre links to ensure:

- robust, resilient Operational Telecommunications with low cyber security risk; and
- a GB wide secure, reliable data and voice network for day-to-day operational management and Black Start operation of the electricity grid.

Introduction of DER into a Black Start process provides a significant challenge to OST. Complications include:

- the volume and types of stakeholders could increase considerably;
- DNOs/DSOs are likely to be performing new roles; and there may be a reliance on other parties like aggregators and generator control centres remote from the resources themselves.

The increase in stakeholder numbers and the variety of stakeholder types are a significant challenge for the OST workstream in developing Black Start processes. They may also lead to a vast increase in the number of data points, and the number and type of potential Operational Telecommunications that could be used (e.g. microwave, satellite) and so represent a potential increased risk in terms of ensuring cyber security and end-to-end power resilience.

Furthermore, although we are considering novel approaches and innovative solutions, such approaches will lead to an initial training burden to overcome a lack of experience. In particular, the DER will not only be unfamiliar with existing procedures but will require new procedures of their own. This challenge should be overcome in time, so although initially expensive/resource intensive, it should ease and eventually end.

2.2 Changing environment:

Both the energy and telecommunication industries are undergoing periods of rapid change. We are monitoring known initiatives to identify where we:

- can gain useful learning; and
- where we need to feed into developments.

Table 2.1 illustrates some of the other important projects, consultations and activities that sit alongside Distributed ReStart.

Alongside specific initiatives, we are working closely with a wide range of stakeholders to ensure that we consider a set of consistent, efficient and economic solutions to meet the project needs and stakeholder business models. Our engagement is described in section 3.

2.3 Telecommunications resilience

Of specific note is the area of telecommunications resilience. Whilst a focus is placed on power resilience, it is essential to consider resilience as a whole, including cyber and physical security issues.

As mentioned above, the current Black Start process utilises a relatively low number of large, well established players using dedicated fibre links between parties with long-standing resilience requirements. Inclusion of DER in the process has significant change and unknowns across all areas of resilience, including:

- what resilience is required;
- what resilience is technically and economically achievable;
- how we gain assurance that the required resilience is provided.

At this point in Distributed ReStart, we do not have a confirmed power resilience requirement. We intend to have a working assumption as soon as possible (see Next Steps in section 17). Alongside this, we will continue to monitor and, where appropriate, work with stakeholders to confirm the actual requirement when possible.

Table 2.1

Table of ongoing projects impacting on the organisations, systems and telecommunications for Distributed ReStart

Type	Timing	Title	Parties	Description	Deliverables/Milestones
Project	01/19–2/10	NIA: Network Islanding Investigation	WPD	Examines localised approaches to balancing the network; mainly looking at commercial side (lV–33V); includes review of islanding overseas.	Q1 2020: final report
Project	End Q1 2020	Distributed generation Cybersecurity Connection Guidance	BEIS	A landscape review of non-domestic distributed generation in GB in consultation with the Distribution Network Operators and policy teams at BEIS. It will include capacity, location and equipment type of generation resources currently in use, as well as a likely future roadmap for this area as energy assets continue to become more decentralised, in consultation with the Distribution Network Operators and policy teams at BEIS.	An assessment of the threat and potential impact of cyber compromise of distributed generation resources. An open source review of similar initiatives across the US and EU, including any relevant standards that are in place. Development of guidance/best practice for secure deployments of distributed generation resources to mitigate the threat from compromise and to consider how it can be incorporated to the ENA connection codes. **Recommendations for further work in this area** An area to consider is how we ensure that new deployments are meeting the standards developed through the guidance and how we account for any deviation. In addition, after deployments how do we ensure secure cyber security controls are maintained.
Project	2020	tbc	BEIS/E3C	Determine Black Start cyber dependencies following cyber outage, including cyber outage likelihood and time of recovery for those systems. Incident readiness.	Work anticipated for 2020.
Legislation/ Codes	In force 12/18, implemen-tation by 12/19	European Emergency Restoration Network Code (NCER)	NGESO, DNOs, TOs, SGUs	NCER sits above UK codes. It requires an System Defence Plan (SDP) and an System Restoration Plan (SRP) to be in place. These plans sit in between the ERNC and the Grid Code etc. ERNC requires resilience of a minimum 24 hours for systems and telecommunications for TOs, DNOs and significant grid users (SGU). (NGESO definition for SGU is anyone with a CUSC contract).	ERNC has been in force since December 2018, to be implemented by December 2019. A number of code changes in place to implement – ongoing.
Legislation/ Codes		System Restoration Plan (SRP) and System Defence Plan (SDP)	NGESO, DNOs, TOs, SGUs	System Restoration Plan (SRP) and System Defence Plan (SDP) conform to NCER and impacts DSOs, TSOs and SGUs. See **https://www.nationalgrideso.com/codes/european-network-codes/meetings/emergency-and-restorationconsultation** SRP defines technical and organisational measures for restoration. SDP enforces assurance and compliance testing for TSOs, DSOs and other SGUs.	NGESO proposals (in SDP and SRP are with Ofgem for approval). Note: Electrical Standard update for control telephony, EDL/EDT; test plan and procedures to be consulted on.
Procurement	Ongoing	BAU tender rounds	Potential Black Start participants, NGESO	Historically, Black Start services have been purchased via bilateral procurement. Now moving onto competitive procurement, providing opportunities for different technologies increasing economic and efficient delivery.	South West and Midlands tender: • Launched in December 2018. • Revised technical criteria – provider required to prove their inertia capability. • Potential providers with different technologies submitted F1/F2 scope reports in July 2019. Next steps: • F2 report submission by April 2020. • Service commencement in April 2022. • Scotland, North East and North West tender: – launched in August 2019 – ITT in November 2019.
Industry groups	Ongoing	E3C and associated groups	Industry stakeholders	ETG/BSTG/CTG/GTG – electricity, Black Start, comms and gas task groups.	

Type	Timing	Title	Parties	Description	Deliverables/Milestones
ENA facilitated industry groups – Strategic Telecom-munications Group	Ongoing	Strategic Telecommuni-cations Group (ENSTG)	ENA facilitated, includes DNOS, JRC, NGESO	ENSCG provides a focus for liaison, co-ordination and information in areas of mutual interest to the ENA member companies. • It promotes the interests, growth, good standing and competitiveness of the UK energy networks industry's Operational Telecommunications and IT services in the UK and overseas. • It provides a forum for discussion, among company members and others, of telecommunication and IT issues and to pass informed opinion on these matters to Ofgem, Ofcom, government departments, and other institutions in the UK and the European Union.	Ongoing
ENA facilitated industry groups	Ongoing	ENA Open Networks project	ENA facilitated, includes DNOS, NGESO	Ofgem/BEIS supported programme looking to develop DSO functions and activities. Of particular note: Workstream 3, Data Transfer WS & Product Ref: WS1B P3.	Has annual published work programme containing deliverables for five workstreams; Flexibility Services, Whole Electricity System Planning & Data, Customer Information, DSO Transition and Whole Energy Systems. Workstream 3, product 3 is taking the outputs of ongoing trials to better define the information transfers that will be needed to enhance transmission/distribution system coordination and control. It is evaluating how these information transfers would change for the future models that are being assessed under Workstream 3.
ENA facilitated industry groups	Ongoing	ENA cyber security Task Group	ENA members	Advise the ENA with regard to cyber security issues affecting the UK energy sector.	Carry out benchmarking. Produce guidance/standards as required.
Industry group	Ongoing	E3CC	E3C members, BEIS, NCSC, Ofgem (associate)	Cyber security Task Group. Risk assessment and strategic programme for cyber security in the energy sector. DER is on the risk list. Some renewables are now partaking in E3CC discussions.	Energy sector risk assessments. producing and driving strategic programme of work, some discrete projects and supplier engagement. Implementation of government regulations/standards etc.
Black Start training	Ongoing	BAU Black Start Workshops	NGESO, TOs, DNOs	NGESO led workshops.	Increase visibility of restoration plans. Opportunity to practise restoration process and communication.
Black Start publications	Ongoing latest version of Black Start Strategy (3rd) issued 8/19	includes: Black Start Strategy	NGESO	The Black Start Standard outlines achievements and NGESO aims: • Restoration timescales: 60 per cent demand in 24hrs – This translates into number of providers required. • Restoration approach – Skeleton. • Probabilistic model. • Technical requirements and its evolution with changing generation landscape. • Combined services. • Short, medium and long-term strategy. • Cost components: availability, warming, CAPEX, testing, feasibility studies. • 2019 also includes a summary of what was achieved in various areas (as stated in 2018 publication). Publications found at: **https://www.nationalgrideso.com/balancing-services/systemsecurity-services/black-start**	Annual publication.

Type	Timing	Title	Parties	Description	Deliverables/Milestones
Legislation/ Codes	ASAP	Black Start Standard	BEIS, Black Start stakeholders	BEIS are proposing a Black Start Standard from Autumn 2019, but yet to confirm. • Implementation of the Standard requires changes in DNO infrastructure – estimated cost already submitted to the BSTG. • Assurance framework being trialled and developed to ensure the Standard can be met. • Impact on non-Black Start power stations being investigated. • ESO implementing the Network Code Emergency & Restoration through a series of code changes. • Introduces requirement on DNO around resilience and monitoring.	Black Start Standard.
Incident reporting	2019	9 August reports	Industry stakeholders	Take account of recommendations etc.	
Project	2018–2019	NIA Black Start from non-traditional generation technologies.	NGESO, SPEN, TNEI	National Grid ESO is looking to broaden the technologies capable of participating in a Black Start so commissioned 3 complementary works delivered by TNEI. These have been used when assessing the current Black Start tender and will be integral to the NIC project. Key outputs include: • Technology readiness level and roadmap, identifying the key blockers to different technologies participating in Black Start. • Power Islanding operations review, based around case studies of low inertia islands focusing on a-synchronous operating. • Wind reliability analysis, a statistical analysis on reliable power output from a contracted total wind capacity over time periods.	Three publicly available reports found on the Distributed ReStart website.
Ofgem Distribution System Operation	2019–2020	DSO Position Paper	Ofgem	Ofgem position paper setting out their proposed approach and strategic outcomes for DSO.	Agreed industry approach to DSO, including treatment of DNOs and contestable services, key enablers, and development of co-ordinated flexibility markets.
Ofgem RIIO-ED2	2019–2023	Open letter consultation on approach to setting the next electricity distribution price control	Ofgem	Open letter consultation setting out Ofgem proposals for RIIO-ED2 price control (running 2023–2028).	RIIO-ED2 price control outcomes for electricity DNOs in period 2023–2028.

3. Industry engagement

Distributed ReStart aims to incorporate the views of wider industry at every opportunity, bringing in the diverse expertise found across multiple businesses in the electricity market.

3.1 Distributed ReStart

To scrutinise the outputs throughout this three-year project, we have established a stakeholder advisory panel to provide industry views on project outputs and planned next steps. Members include a range of industry experts including academics, industry experts, BEIS, Citizens Advice, Energy Systems Catapult, Cornwall Insights and the ENA.

The panel's first meeting was on the 18 September 2019. This event focused on reviewing the key conclusions from the Power Engineering and Trials Viability Report **https://www.nationalgrideso.com/document/149961/download**

In addition to these project-wide initiatives, as a workstream, we are engaging fully with our key stakeholders and working with the other Distributed ReStart workstreams to maximise the efficiency and effectiveness of discussions.

In terms of gathering information from DER, the principal approach to date has been through questionnaires and via discussions with potential participants in the live trials. Further detailed discussions with DER and aggregators are an important next step.

An example of the questionnaire is given in the appendix (section 19.1).

3.1.1 DNOs and TOs

Significant investment has been made in gathering views from DNOs/TOs due to their pivotal role in any future Black Start process. We will continue to engage through workshops, bilateral meetings, industry groups and other project initiatives.

As SPEN holds both transmission and distribution network licences, we have full integration of a TO within the project team. In addition, we have engaged with all other onshore TOs across GB to solicit their input. Engagement to date has included face-to-face meetings, web conferencing and the use of questionnaires to gather information on current Operational Telecommunications and invite inputs to our organisational assessment. We will maintain active dialogue with TOs throughout the duration of the project.

For example, on 12 September, the project hosted an event inviting DNOs and TOs to share their views on the future of restoration. This event focused on confirming 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. The outputs of the workshop are captured in a document published on the project website: **https://www.nationalgrideso.com/document/153861/download**

Specific learning points and engagement are noted through the report.

3.1.2 Distributed Energy Resources

The principal approach to gathering information from DER has been through questionnaires as noted above. In addition, we have joined with the PET workstream for discussions with potential participants in the PET live trials. As noted in section 17, a next step for OST will be further detailed discussions with DER and aggregators across all areas of OST.

3.2 Wider industry

3.2.1 Energy Network Strategic Telecommunications Group (ENSTG)

Since July 2019, we have been attending the ENSTG. This group is facilitated by the ENA and provides a focus for discussion and coordination of its DNO, TO and SO members and the Joint Radio Company (JRC) to identify and share how Operational Telecommunications are transforming and what enhanced capability is needed to address current and future challenges.

Through sharing our thinking on Operational Telecommunications options with the ENSTG, we have gained valuable feedback, informing our next steps and re-emphasising the variety of telecommunications solutions, hence our 'no one size fits all' approach.

Terms of Reference can be found at: **http://www.energynetworks.org/electricity/engineering/energy-telecommunications.html**

3.2.2 OFCOM

We have already had some fruitful discussions with OFCOM. Initially via the ENSTG and subsequently through bilateral dialogue. To date, our discussions have focused on ensuring that we are considering all viable options for the Operational Telecommunications and that our initial review is credible.

Specifically, OFCOM have put forward telecommunications options that are likely to become available in the next few years, which we have included in our initial review.

3.2.3 JRC

We have gained valuable feedback from JRC bilaterally, via the ENSTG, and at their annual conference themed 'The UK Smart Grid Vision' (11 September 2019).

Suppliers, manufacturers and service providers

Distributed ReStart is engaged with several leading suppliers to gather and develop design requirements for systems to support inclusion of DER in Black Start, and to assess potential technology and solutions available to deliver cost effective power resilient Operational Telecommunications. Further engagement will follow with a wider range of providers.

3.2.4 Existing Black Start service providers

OST has met with a number of conventional service providers. Of particular note is our participation in Local Joint Restoration Plan (LJRP) reviews and workshops.

3.2.5 Interested stakeholders

Over 100 stakeholders have been engaged through project webinars. Any questions submitted have subsequently been published with answers on the Distributed ReStart website: **https://www.nationalgrideso.com/innovation/projects/distributed-restart**

Further engagement has been achieved through Utility Week Live, the Power Responsive conference, LCNI and the NGESO Customer Connection seminars to reach broader industry stakeholders, and we will continue to interact with interested parties through conferences, projects and events over the coming months including the Operational Forum, use of social media and via the project website **https://www.nationalgrideso.com/innovation/projects/distributed-restart**

Global interactions include:

- GO 15, through senior managers within the wider project;
- project representation on a relevant CIGRE working group;
- submission of a paper in early 2020 to CIRED; and
- discussions with European energy companies.

Our annual conference, scheduled for 30 January 2020, will deliver our current learning outcomes and outline our ongoing engagement.

3.2.6 Engagement with projects

In such a dynamic world, engagement and knowledge sharing with other projects and initiatives is vital for OST to develop appropriate solutions.

To date we have had discussions with or about a wide range of projects, including those listed in table 2.1.

3.2.7 Continued engagement

The project continues to reach out to a broad stakeholder base and is actively seeking ways to engage with businesses of all sizes – through project updates, the Stakeholder Advisory Panel Forums and Industry Advisory Groups. The above is represented in the Stakeholder and Engagement Plan which details cadence and approach with the different areas of interest.

Through these events, a strong industry interest in the project has been established, reaching over 300 registered participants.

4. General approach

The general methodology applied to each area (Organisational and Operational Telecommunications) is described below.

Our focus to date has been to identify the challenges and issues that will require resolution during the next phase of the project. Alongside this, we have considered a wide range of options available to meet these challenges. As we move into the design of future processes, roles, systems and telecommunications, we will undertake a deeper analysis of the available solutions.

4.1 Step 1: Current state

Step 1 has been to confirm our current state. We have considered the mechanics of how the current Black Start process works, its efficiency, and what we currently enjoy in terms of Operational Telecommunications (functionality and resilience).

4.2 Step 2: Key requirements for Black Start

In parallel with step 1, we have undertaken extensive stakeholder consultation, to extract the generic requirements for any Black Start process. Our stakeholder discussions to date have predominantly, but not exclusively, focused on DNOs, TOs and the DER within our case study areas [1]. Workshops are planned over the coming months to extend the depth of our engagement with other potential Black Start participants and academia.

4.3 Step 3: Changing environment

We are working with a wide variety of stakeholders to identify both the challenges of incorporating DER into the process and the changes taking place across the relevant industries (energy, and telecommunication (including cyber)).

In addition to the increased number of stakeholders and associated challenges mentioned earlier in the report, many initiatives and changes are either ongoing or expected over the next few years.

Significant changes occurring during the next five years include:

- the public switched telephone network (PSTN) switching off by 2025
- introduction of 5G (and 2G/3G becoming obsolete)
- government policy to extend fibre to all premises by 2025
- imminent introduction of Black Start Standard
- introduction of the European Emergency Restoration Network Code (NCER) and associated System Restoration Plan (SRP) and System Defence Plan (SDP).

4.4 Step 4: Future-proofing

Examining the changes expected over the next few years will allow us to future-proof our proposals as they are developed in the next phases of the project.

4.5 Step 5: Options

In looking at the alternatives available to meet the needs of developing a Black Start process to facilitate the use of DER, we have intentionally taken all widely-known options through a high-level review.

As we progress through the next phases of the project, we expect some options may be parked and others taken forward. We do not expect to recommend a single option (either Organisational or Operational Telecommunications), but instead anticipate a combination of options will meet the project and stakeholder needs.

5. Assumptions

In this section, we present the assumptions that are particularly important to this workstream

5.1 Workstream assumptions

As a project, Distributed ReStart has a project-wide set of assumptions, assumptions that are either OST-specific or of particular importance to this workstream are noted here to provide a basis for the following analysis. These sit alongside the technical assumptions made by the PET workstream, and the regulatory and procurement assumptions made by the P&C workstream in the initial reports on **https://www.nationalgrideso.com/innovation/projects/distributed-restart**

Assumptions and requirements that are specific to individual elements of our analysis sit in the appropriate sections of the report.

5.2 Processes and responsibilities

National Grid ESO will continue to be responsible for national coordination of the Black Start restoration process.

It is, however, noted that the manner in which this is delivered may change as new service providers are introduced.

Distributed ReStart must deliver a set of proposals that fit into or support the existing Black Start process.

Any DER-led restoration process established by Distributed ReStart will follow a phased roll-out where the existing Black Start process, contracting and assurance are still used.

5.3 Resources

Sufficient training will be provided post Distributed ReStart to facilitate the implementation of any proposed processes or skills. Note:

- An increase in the number of Black Start participants may result in a significant increase in training requirements.
- New simulator/power system modelling tools may be required to allow users to prepare, test and practise for different events, and review historical events.

Post Distributed ReStart, new systems/routines/automatic schemes will be included in any testing regimes associated with the delivery of Black Start services or contracts.

Communication systems between Black Start participants will be subject to ongoing testing with Black Start users.

5.4 Clarity and simplicity

Complexity in all processes and technologies relied upon for Black Start should be minimised wherever possible.

5.5 Visibility

We assume that control engineers will require visibility of the following to allow them to take informed actions during a Black Start:

- Where relevant to the Black Start process, plant status and condition of the DNO network.
- DER availability and generation parameters, e.g. time to synch, minimum load required, block load.
- Demand sources that can be connected to stabilise and increase DER output.
- Demand information, e.g. cold load pick-up, historic demand information, embedded generation connected.
- Voltage information required throughout the network to regulate voltage levels.
- Frequency monitoring sources throughout the network and at DER to allow islands to be coupled.
- Information on additional DER that could be used to grow the network or reduce Black Start DER output.
- Weather information allowing a forecast of wind/solar DER output to be developed.

Organisations

6. Organisational introduction

The capability of organisations to deliver a Black Start procedure is critical to the overall success of restoration. Through engagement with existing Black Start participants, we have reviewed both existing capabilities and potential organisational change requirements.

The role of control room staff, and the nature and volume of their work, can change significantly from normal operations to that during a Black Start. During a Black Start event, shift teams are reorganised to manage the restoration in a co-ordinated and efficient manner together with effective co-ordination of additional/relief staff as required. The organisational structures used by each stakeholder in a Black Start are intrinsically linked to their agreed processes and roles and this will persist in any proposed solution.

The purpose of the analysis in this section is to develop a baseline capability of organisations during this distressed operating scenario from which we can compare potential options for organising a Distributed ReStart.

6.1. Approach

A review of the companies, people and processes used to facilitate the existing Black Start plans has been produced through extensive stakeholder consultation. This review covers National Grid Electricity System Operator (NGESO), the Onshore Transmission Owners (TO), all of GB's Distribution Network Operators (DNO) and consideration of Distributed Energy Resources (DER).

A set of models have been developed to illustrate their capabilities in facilitating a Distributed ReStart. These represent extreme options for control of a Black Start and levels of automation. They have been created to enable the project to understand possible change requirements but remain flexible to meet the DSO worlds being developed through the ENA Open Networks project and wider industry changes. These models will be developed and refined in the next phase of work to define processes and the party responsible for enacting these. Publication of these will form part of the second set of Organisational Systems and Telecommunications deliverables for October 2020.

6.2. Organisations in Black Start

The organisational structures and processes used by each stakeholder in Black Start centre around the current Black Start strategy **https://www.nationalgrideso.com/balancing-services/system-security-services/black-start**

The current Black Start process uses commercial contracts with mainly transmission connected providers to assure appropriate technical and procedural capabilities are in place to support system restoration. There is an obligation on NGESO under Grid Code CC6.3.5 to ensure capability is available to energise the Main Interconnected System (MITS) if Black Start is declared. **https://www.nationalgrideso.com/codes/grid-code**

To ensure capability is available to energise the Main Interconnected Transmission System (MITS) if Black Start is declared. Multiple providers are contracted across several Black Start zones to ensure the restoration capability meets strategic timescales and that there are always providers available should an event occur regionally or nationally. These contracts are centred around Local Joint Restoration Plans (LJRP) [2].

LJRPs are quadripartite agreements between NGESO, the relevant TO, the relevant DNO and the contracted Black Start service provider. This agreement specifies the provider capability, the likely available distribution network demand, and typically several transmission system restoration options.

Each organisation involved in the LJRP is resourced according to an internal structure that the relevant company believes facilitates its role in an LJRP. The role of assuring this capability belongs to the NGESO National Control function, including assurance of appropriate skills, systems and personnel to deliver against it.

If an event occurs, ownership of the Black Start process belongs to the NGESO Power Systems Manager (PSM). All instructions issued by NGESO are treated as Emergency Instructions from the moment of declaration until official declaration that the event has ceased. The technically optimal method for restoring power supplies after a major failure event is prioritised and the electricity market is suspended to facilitate this.

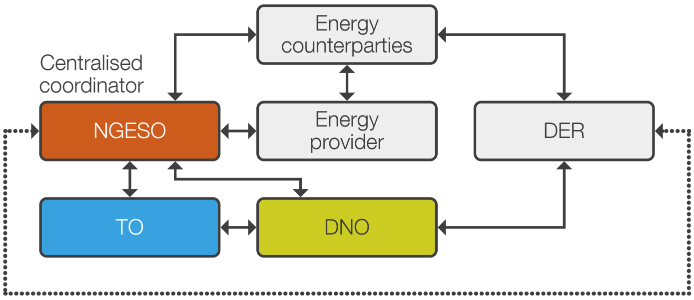
7. Existing arrangements

This section contains a review of the existing organisational structure through an analysis of the companies, people and processes involved in Black Start.

7.1 Companies

The companies involved in a Black Start include: National Grid Electricity System Operator (NGESO); all of GB's Transmission Owners (TO); all of GB's Distribution Network Operators (DNO) and Black Start service providers (Providers). Outside of Black Start, these parties continually work together to deliver an efficient reliable network using the communications interfaces from figure 7.1. However, Black Start is an onerous situation, with specific operating protocols, as described throughout this section.

Figure 7.1
Communication interfaces for normal system operations



7.1.1 National Grid Electricity System Operator

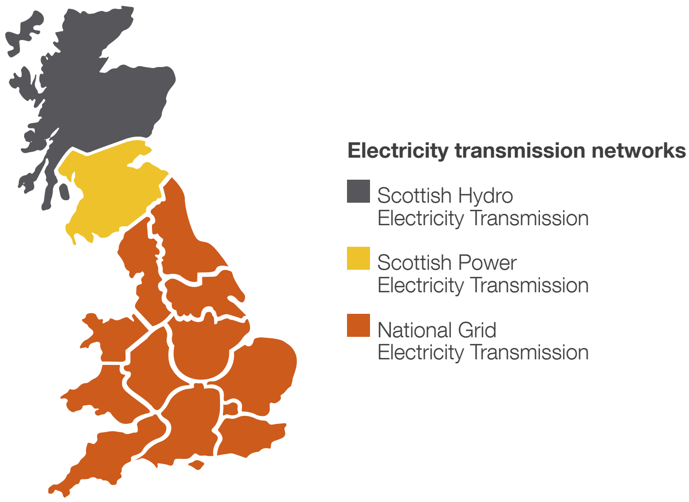
National Grid Electricity System Operator (NGESO) is the company responsible for the efficient operation of Great Britain's Main Interconnected Transmission System (MITS) and all directly connected assets. Under normal operations, it has strategic control of the electricity transmission system and may issue instructions but does not enact physical switching, except where automatic processes are pre-agreed with the relevant party. Under a Black Start scenario, NGESO assumes overall control of the event with the Power System Manager from its Electricity National control centre (ENCC) becoming the overall Black Start controller.

NGESO is responsible for the provision and assurance of the overall Black Start service before the event as part of its Grid Code obligations. Local Joint Restoration Plans are developed by NGESO in conjunction with all other parties involved to define basic technical parameters and responsibilities in advance of a Black Start event.

7.1.2 Transmission Owners

The TO is responsible for building, maintaining and operational switching of the MITS under normal operations. The transmission system includes all circuits which operate at 400kV or 275kV in England and Wales. In Scotland, 132kV is also a transmission voltage level. There are three companies which have responsibility for this in Great Britain: National Grid Electricity Transmission (NGET) in England and Wales, Scottish Power Transmission (SPT) in Central and Southern Scotland, and Scottish Hydro Electric Transmission (SHETL) in Northern Scotland (see figure 7.2).

Figure 7.2
Map showing location of transmission licence areas and respective DNO licence area boundaries



Under a Black Start scenario, NGESO will declare Black Start enabling the TO to begin their internal Black Start processes and establish an interface with the relevant DNO. The TO is then responsible for reporting all adverse network conditions to NGESO and completing the physical switching actions that enable the Local Joint Restoration Plan (LJRP) option selected by NGESO. At any time during the recovery period, NGESO can instruct the TO to cease an LJRP and resume complete control of networks.

In Scotland, it is possible with pre-agreement or loss of communications for the TO to accept responsibility to enact the LJRP within their zone without NGESO oversight until interconnection with another LJRP. This provides redundant capability and additional capacity to manage multiple LJRPs in parallel, facilitating a faster restoration.

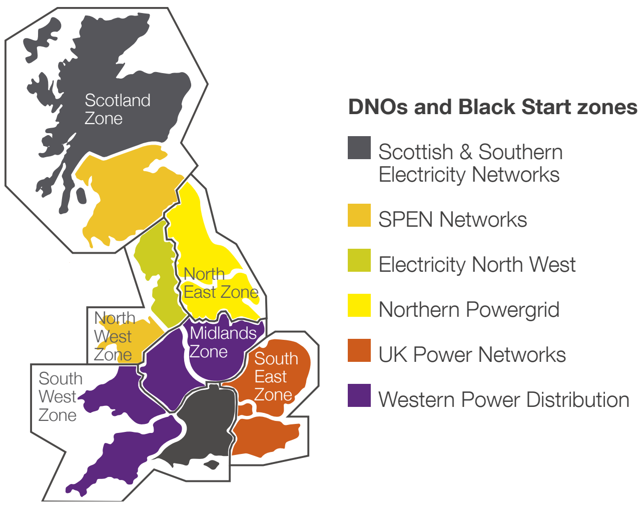
Due to the high-power demand and large number of transmission circuits across England and Wales, compared to Scotland, there are multiple zones and hence multiple LJRPs within this transmission licence area. Therefore, the LJRP controller function will remain with NGESO as it would be impractical for NGET to manage a Black Start in this manner.

7.1.3 Distribution Network Operators

The DNO is responsible for building, maintaining and operating the distribution network within their distribution network licence area depicted in figure 7.3. The distribution network covers all circuits from 132kV and below in England and Wales and 33kV and below in Scotland. There are 14 DNO licence areas covered by six different companies.

Figure 7.3

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



In a Black Start, DNOs are responsible for all switching actions to segregate their networks into predefined blocks of demand for the initial stabilisation of a generator in a LJRP and all other switching actions that facilitate the wider restoration of demand. Not all DNOs have a LJRP within their area, in this case they would not be involved in the Black Start process until the LJRP phase is over.

7.1.4 Black Start service providers

Not all generation is required to have Black Start capability, instead commercial procurement ensures that up to three providers are contracted per zone as depicted in figure 7.3 [3]. This allows for a geographic spread of restoration capability, which is important due to the reactive power requirements of energising the MITS over long distances. A provider must be technically capable of accepting block loads of between 20MW–50MW [4] and providing 100MVAr leading reactive power capability, this restricts the minimum size of participating plant to 102MVA [5] but typically requires a significantly larger unit to provide the reactive power capability and accept multiple block loads.

It is the responsibility of the provider to meet the technical capability procured but this may be split into multiple parties providing self-starting, transmission energisation and block loading capability separately in a single plan using co-location to establish the full service. Provider classifications procured are shown in figure 7.4.

Figure 7.4

Currently procured Black Start services

Conventional Black Start **Large provider** ☑ Self starting ☑ Energise NETS ☑ Block load capability	**Black Start enhanced restoration** **Large provider** ☒ Self starting ☒ Energise NETS ☑ Block load capability	**Black Start embedded** **Large distribution embedded provider** ☑ Self starting ☑ Energise NETS ☑ Block load capability
Trip to house load (Readiness provider) **Large provider** ☒ Self starting ☒ Energise NETS ☑ Block load capability	**Interconnectors full service** ☑ Self starting ☑ Energise NETS ☑ Block load capability	**Interconnectors fast start** ☑ Self starting ☑ Energise NETS ☒ Block load capability

7.1.5 DER

A DER is any form of energy resource (inclusive of batteries and energy storage resources) installed on the distribution network, rather than the transmission network. There is no specific size requirement for the project to consider an energy resource as a DER but all installations at 11kV and below which do not directly transform to 132kV are deemed out of the scope of this project [1]. DERs do not play a part in the existing Black Start structure but some larger distribution connected generation may be considered in future Black Start procurement if they can meet the Black Start criteria [5].

7.1.6 Interface map

Under a Black Start, the interfaces change from the normal operational scenario (figure 7.1) to the simplified telephone communications displayed in figure 7.5. For the specific process of block loading, an open line is also established between the provider and DNO to enable rapid stabilisation of the provider through load management as depicted in figure 7.6.

Figure 7.5

Current Black Start communications map outside of block loading

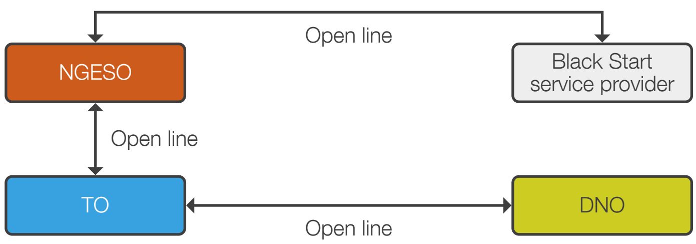
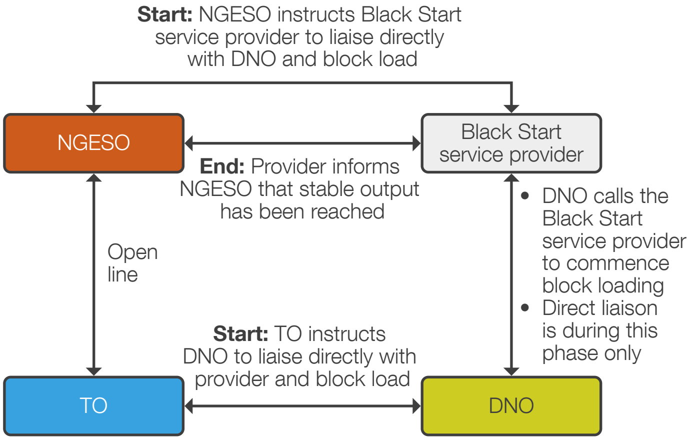


Figure 7.6
Black Start communications map during block loading



7.2 Current processes

The existing Black Start process can be broadly split into five key phases:

Initiation and declaration: Specific actions are focused around automated responses to loss of supplies, network preparation and information gathering which would enable the strategy to be developed and LJRP route to be instructed.

System energisation involves generating a voltage source to all substations involved in the LJRP enabling connection of loads.

Block loading involves stabilising the generator through providing small amounts of DNO demand in steps.

End of the LJRP is declared when multiple energy resources or multiple DNOs are involved in the same Power Island. Growing the Power Island involves coordination of multiple providers, DNOs and TOs, therefore full control returns to NGESO after this point.

Expansion and synchronisation of the Power Island: Growing the Power Island(s) involves coordination of multiple providers, DNOs and TOs, therefore full control returns to NGESO during this phase. This state is maintained until a declaration from the NGESO Power System Manager that Black Start is ended.

Table 7.1 details the actions which should be taken and the parties responsible for the decisions and the enactment of these whilst following the process outlined above [6].

Table 7.1
Current processes under a Black Start

	Phase	Responsible party	Actions required
Initiation and Declaration	**Trip to house load**	Provider to begin internal processes automatically	On loss of mains, providers of the trip to house load or Black Start services should revert to this mode of operation.
	Declaration of Black Start	NGESO	NGESO to declare a Black Start and suspend the market. All parties to acknowledge and begin internal readiness procedures.
	Prepare internal processes	All parties	DNO: Confirm last known available load at each GSP which may provide demand during an LJRP. Call in any required additional resource. Begin segregating network to provide block loads. TO: Begin isolating the network, opening all circuit breakers and confirming transmission network status. Provider: Confirm availability of the Black Start service, estimate time required to enact and investigate any changes to plant from the uncontrolled shutdown which may impact on delivery. Call any desired support staff to site. NGESO: Set up command and control structure.
	Assessment of network and generator status	All parties	DNOs, TOs and providers to confirm any deviation from the assumed capabilities of the LJRPs they are party to.
	LJRP enacting and option confirmation	All parties	NGESO to confirm LJRP option to be used, provider to begin start-up process, DNO to segregate network, TO to configure network to facilitate. NGESO may also agree with a Scottish TO that it should become the LJRP controller for its licence area.
System Energisation	**System energisation preparedness**	Provider and TOs	Provider to trigger through confirming the unit is ready to begin energisation. TO to confirm readiness to energise network.
	Coordinate energisation time	All parties	TO, DNO and provider to confirm readiness, NGESO (or Scottish TO acting as LJRP controller) to instruct energisation of the transmission system.
	Instruct energisation	Provider and TOs	Provider to begin energisation, TO to complete switching programme up to the end of energisation phase.
	Confirm energisation	Provider and TOs	Provider and TO to confirm energisation to agree transmission circuits energised to the point of DNO demand GSP.
Block Loading	**Block loading readiness**	Provider and DNO	Provider and DNO to confirm readiness to begin block loading.
	Block loading	NGESO; DNO or Scottish TO; and provider	NGESO (or a Scottish TO acting as LJRP controller) to instruct commencement of the Block Loading Process. DNO (TO in Scotland) and provider to open a direct line. DNO to provide block loads of pre-agreed maximum size allowing appropriate time between blocks as per the LJRP until a stable power is achieved.
	End of block loading	NGESO and provider	Provider to confirm the unit is stable. NGESO (or a Scottish TO acting as LJRP controller) to take control of load management.
Power Island Growth	**Expand the Power Island**	NGESO/TOs	TO to switch network to grow transmission network skeleton as instructed or agreed Local Joint regional plans. DNO to energise further demand per NGESO (or a Scottish TO acting as LJRP controller) instruction.
	Synchronise Power Islands and/or additional generation	NGESO/TOs	Where a Power Island contains more than one generator or more than one DNO area, the LJRP is ended. All processes return to NGESO control.
	End of an LJRP	NGESO	All parties to acknowledge LJRP has ceased.
	Continued transmission growth	Dependent upon the generator and transmission availability NGESO to instruct strategy	TOs switch to facilitate generator and load energisation. Until Black Start is ended, all instructions from NGESO are treated as emergency instructions and all generators must deliver requested output regardless of commercials.
End of Black Start		Power System Manager (NGESO)	All parties to begin commercial operation per normal processes.
Settlement		OFGEM/ELEXON/ NGESO	Settlement from a Black Start event would be at the regulator's decision.

7.3 People

The capability of an organisation to deliver against a Black Start plan will depend greatly on their personnel. To provide a basic analysis of this capability the categories of control staff, support staff, skill requirements and training processes are used. Control staff are defined as those who are operationally responsible for delivery of the Black Start plan should an event occur, whereas support staff are those responsible for pre-shutdown Black Start actions, non-operational roles during the event or site-based engineers who may enact physical switching.

7.3.1 National Grid Electricity System Operator

Table 7.2
NGESO personnel summary

Categories	Key details
Control staff	Minimum of 23 authorised control staff able to control six LJRPs simultaneously
Support staff	Black Start & Business Continuity and Contracts teams provide procurement and assurance Silver Command team provides tactical response
Skill requirements	Overall event leadership Strategic LJRP management Balancing actions Transmission strategy Strategic communications
Training processes	Rigorous authorisation process Specific yearly simulator training Octennial training per LJRP with all signatories

Control staff

The control staff for National Grid Electricity System Operator is based around the control engineering shift team for the Electricity National control centre (ENCC).

A full ENCC shift team consists of 23 people split into functions of energy balancing, transmission and strategy. Under normal operating conditions, the Energy Balancing team are responsible for the real-time management of frequency through generator and demand instructions. The Transmission team are responsible for the real-time management of the transmission system, ensuring pre and post fault actions are optimal, and voltage is kept within statutory limits. The Strategy team is responsible for longer-term operations across energy balancing and transmission up to 24 hours in advance of delivery.

The Black Start procedures for the ENCC make best use of these existing skill sets during a Black Start event through organising into five distinct control functions:

Command and Control is led by a Power Systems Manager (PSM) with support of a Control Technical Assistant.

Initially, the PSM's responsibility is to declare a Black Start event, this is the trigger to formally suspend the Balancing Mechanism and this message is communicated to all relevant parties. The time is noted. From here on, Command and Control is responsible for overall control of the Black Start event.

Variations to the staffing can be instructed by the PSM and may include adopting shorter control shifts or changes to facilitate better communications.

Furthermore, the PSM will implement a command and control structure including set-up of a tactical advice function (Silver Command) which will manage information dissemination between senior leaders, government, media, and the shift team responsible for implementing the technical restoration process and focus on longer-term issues with restoration.

Generation and Demand Despatch led by an Operational Energy Manager, inclusive of a National Balancing Engineer and an Assistant National Balancing Engineer.

Following declaration of a Black Start, this function is responsible for initial discussions with Black Start service providers which will be used to assess the readiness of a provider, the timescales in which any service can be delivered and any relevant technical restrictions that may apply during the provision of service. They will initially gather relevant parameters which will be used to assess the viability and order of usage of the various providers. An important aspect of this is the coordination of generation with available demand which may not necessarily be in a similar state of readiness to the generation resource and so could delay a particular LJRP.

Often, the timescales for delivering a certain state of readiness are limited so need to be controlled carefully and are functions of such parameters as readiness of plant, warmth of plant and available fuel supplies if applicable. It is not the responsibility of the Energy team to carry out the initial balancing of generation and demand under a Black Start event as this initial balancing is carried out bilaterally between the generator, through delivery of energy, and DNO, through delivery of approximate matching of demand in block loads. This is a crucial difference between BAU and operation under a Black Start. When Power Islands include more than one energy provider or more than one DNO, the LJRPs are officially suspended and the Energy team in NGESO reverts to the frequency controller (the act of balancing supply and demand) for the island.

Communications and Strategy led by an Operational Strategy Manager, inclusive of a National Scheduling Engineer (or Assistant National Scheduling Engineer), and a Transmission Analysis Engineer.

This team is responsible for coordinating and establishing the availability and capability of non-Black Start energy providers to create a forward-looking schedule of availability. They are also responsible for any further staff resourcing which the PSM may instruct, until a Silver Command function is established, inclusive of establishing the capability of subsequent shift teams to attend site given the travel disruption which may follow an event.

Whilst it is expected that no further staff resourcing is required to manage the event, immediately after a shutdown NGESO would endeavour to contact staff members with control authorisations. Where required, available staff would endeavour to attend site as soon as possible to enable transition to shorter shifts.

Transmission Restoration team led by a Transmission Security Manager, Transmission Security Engineer(s), Transmission Analysis Engineer(s) and Day Ahead Congestion Forecasting Engineer(s) (DACF).

The Transmission Restoration team are responsible for developing a restoration strategy and enabling configuration of the transmission system to facilitate LJRPs and wider system restoration. This team is not authorised to switch on the MITS, however, they shall direct the relevant Transmission Owner to enact their agreed LJRP and also agree any deviations from the agreed plan.

Additional Staff are allocated dependant on skill level to the teams detailed above but do not have a specific allocated role. Transmission Analysis Engineers, Training/Assistant Transmission Security Engineer(s) and Training/Assistant Balancing Engineers are categorised as additional staff [7].

This command and control structure enables management of a total of six LJRPs concurrently but can facilitate two additional Scottish LJRPs through delegation of the LJRP controller role to the respective Scottish TO.

Support staff

The principal support staff involved for NGESO are the Black Start and Business Continuity Team, the Contracts Team and ENCC Silver Command.

The Black Start and Business Continuity team, in parallel with the Contracts Team, are responsible for setting Black Start service requirements and the economic provision of the service across all Black Start zones through procurement of bilateral contracts. Furthermore, they are responsible for conducting tests at Black Start contracted sites and assurance of the Black Start process.

During a Black Start, Silver Command will be established. The purpose of this is to provide a tactical response to the incident, inclusive of maintaining direct communications with senior leaders and government, in addition to supporting tactical decisions. The ENCC Silver Command team consists of an Incident Controller, a Log Taker to maintain a defensible decisions log and a Communications Coordinator. Subject matter experts may also be requested from office day staff or otherwise but are not on a rota. It is expected Gold Command will also be enacted and will be a key point of contact for external communications.

The Crisis Management Team will also be established for management at a company level. This is not directly involved in the Black Start process but will provide strategic direction through the Silver Command function [8].

Skill requirements

In its overall role as Black Start controller, NGESO allocates specific roles to ENCC control staff which are aligned to existing authorisations and normal operational roles.

The Command and Control team must be capable of viewing the restoration strategically, making decisions on resource allocation or available skill sets. They must liaise with the ENCC Silver Command team to keep them informed of operational information and respond to strategic direction set by senior leaders and government.

The Communications and Strategy team must be capable of maintaining an updated generator plan for all non-Black Start stations through direct liaison with power station staff. They must also be able to schedule generation in line with a restoration strategy and provide input to Silver Command, inclusive of managing the initial Communications Coordinator role from Silver Command until this is established.

The Generation and Despatch team must be capable of collating information on Black Start units and instructing LJRPs in line with a national strategy. They must manage generation despatch within Power Islands and after the LJRP ceases (an additional generator or an additional DNO are electrically connected) they are responsible for the maintenance of frequency within a Power Island.

The Transmission and Restoration team must be able to develop and instruct the national restoration strategy, inclusive of instructing LJRPs and post LJRP transmission route selection.

The ENCC Silver Command team must be able to take and disseminate strategic and operational information in an appropriate format for the intended audience. They must have formal communications training relevant to the role and have participated in mock scenarios. [7]

Training process

All ENCC staff must be authorised to perform their specific role, this covers the skills and knowledge which will be needed to perform their role under a Black Start. However, specific knowledge is built and reinforced through a yearly desktop exercise on a bespoke simulation of a national blackout being used to develop an understanding of the processes which must be enacted.

There is a requirement for desktop exercises to be conducted once every eight years [9] for each LJRP with the relevant TO, DNO and Black Start service provider. In some cases, this will be shared with the desktop exercise.

Biennially, all ENCC Silver Command Incident Controllers are expected to be involved in bespoke exercise-based training which also happens in parallel to the Black Start training [7] [10].

7.3.2 Transmission Owners

Table 7.3
TO personnel summary

Categories	Key details
Control staff	Variable depending on adverse conditions and time of day, minimum staffing 1 person in each Scottish TO, five people England and Wales. Text alert system and default policies to get additional staff to site.
Support staff	Principally field staff. Command and control functions. Planning roles may also support control staff.
Skill requirements	Transmission switching authorised engineers. Authorised substation engineers. Scottish TOs also require: LJRP management. Balancing actions. Transmission strategy.
Training processes	Rigorous authorisation process. Biennial desktop exercises. Octennial training per LJRP with all signatories.

Control staff

The task to recover from a Black Start situation will be extremely onerous on the Transmission Control Room with the different elements needing to be separated and clearly defined with areas of responsibility allocated according to the following roles: Control Room Manager/Senior Control Engineer(S), Control Room Liaison Engineer(s), Transmission Control Engineer(S) and Telecommunications/SCADA Support Engineer(s) which are broadly consistent across all TOs. Minimum staff resourcing will not be able to facilitate all these roles, hence additional control staff and key site-based personnel will be alerted to the event by a text messaging service and default self-starting protocol.

National Grid Electricity Transmission's control room is called the NGET Control (Formerly Transmission Network control centre (TNCC) prior to legal separation). This control room has 15 team members during week-day rotas, but this drops to a minimum of five people during nights, evenings and weekends. The team consists of a Control Room Manager, Zonal Managers, control engineers and assistant control engineers. It is anticipated that even under out-of-hours conditions, the initial Black Start processes will be possible to facilitate without further resource, although up to 15 additional control engineers may be needed to enact more complex switching procedures during later phases of restoration [11].

SPEN has both transmission and distribution licences which it operates as a single team. Under normal working day shift patterns there are 7–8 staff members covering both transmission and distribution with two Transmission Control Engineers and one Planning Engineer covering the transmission function directly. However, out of normal working hours this can be reduced to one Transmission Control Engineer, who could also be the Senior Control Engineer, and two Distribution Control Engineers.

Scottish Hydro Electricity Transmission operate both transmission and distribution licence areas in the north of Scotland as a single control team. Resourcing during the day is variable dependent upon adverse conditions and outages but the minimum transmission staffing is one Transmission Control Engineer overnight and two Distribution Control Engineers.

Across all TOs, a self-starting policy is used to get key people to site after a suspected event. A text messaging alert service is also used to alert staff but is not relied upon. Initial stages of the event should be manageable even under minimum resourcing but on call resource would be needed for relief and additional support [12].

Support staff

Across all TOs, field staff may be called to key substations in an LJRP to manage the incident and ensure appropriate manual overrides are implemented if required, with key personnel assigned self-starting locations and roles. Resourcing is not specific to a substation and these sites are not manned out-of-hours. Therefore, Substation Technicians, Senior Authorised/Authorised Persons and Commissioning Engineers may be alerted to attend site using a text messaging system [10]. All transmission substations have resilient voice communications from transmission network-owned telecommunications systems. This means after engineers are brought to site, direct instructions can be issued by control staff.

Scottish TOs can become an LJRP controller for those located within their DNO area. To facilitate this additional role, they must resource Generation Despatch Engineer(s) and Load Management Engineer(s) in addition to the common roles and may require further Transmission Control Engineer(S) to information gather and select transmission restoration options. Whilst acting as LJRP controller, there is still need for NGESO to act as overall coordinator as each TO has a single LJRP. This process facilitates management of two further LJRPs expediting system restoration timescales.

Due to the complex nature of managing this scenario, more than one person may be required to carry out each function at any one point in time. It is anticipated that additional Transmission Control Engineers would be the principal facilitators of these but planning teams with switching authorisations may provide further support.

It is vital that control engineers do not become overwhelmed with the scale of the event; command and control structures will enable the tactical response, the exact nature of this team is highly dependent on the business and out of scope of the project to change.

Skill requirements

The overall role of the TO during a Black Start is to facilitate transmission system switching and monitoring and enable synchronisation of Power Islands in later phases of restoration. Furthermore, it is the role of the TO to liaise with the DNO on behalf of the ENCC for the duration of the LJRP.

To perform this, it requires Transmission Control Engineers who, as a minimum, must be authorised to switch in the area of the LJRP they are managing, must understand the LJRP switching plan, must be capable of updating SCADA and must be capable of relaying information to the relevant DNO. [7] Each company will hold its own specific authorisation process, but the requirements are common across all TOs.

Scottish TOs may adopt the role of LJRP controller under conditions where communications are lost or there is an agreement between parties. Therefore, capability must exist within the organisation to enact all NGESO roles as detailed above. The limitation to a single LJRP and lesser availability of conventional generation means fewer people are required to facilitate the roles of Communications & Strategy; Generation & Despatch; and Transmission & Restoration [7].

Training processes

All transmission control staff must undergo an authorisation to be able to perform their specific role outside of Black Start conditions, this will equip them with the general knowledge and skills needed to facilitate the switching requirement for a Black Start. This is reinforced through a Biennial 1-day joint exercise with NGESO on a bespoke simulation of a national blackout to develop an understanding of the processes which must be enacted, this process is common across all TOs [10].

Scottish Transmission Control Engineers must also have basic training on the LJRP controller role. To do this, Transmission control engineer's training packages include emergency scenarios and competence in using generation to restore the network.

The Operational control centre Black Start document and LJRPs also provide information on generator transformer settings, voltage control, system gains from energising the network and the limitations of the Black Start generator.

7.3.3 Distribution Network Operators

Table 7.4
DNO personnel summary

Categories	Key details
Control staff	2–5 Authorised Distribution Control Engineers (DCE) per licence area. 1–3 Control DCE needed per LJRP, dependent on scripted segregation.
Support staff	Principally field staff. SCADA engineer support requirements. Planning roles may also support control staff.
Skill requirements	Command and Control. Demand management. Generation management. Distribution network switching.
Training processes	Rigorous authorisation process. Minimum of training with DNO once every eight years per LJRP. Typically, yearly training but inconsistent in delivery method.

Control staff

Resourcing for day shift conditions will be highly dependent on adverse conditions and outages being taken. However, standard day shift conditions have approximately five Distribution Control Engineers including the room manager which is often a Senior Distribution Control Engineer. Under minimum resourcing conditions, there may only be two Distribution Control Engineers per licence area in England and Wales. In Scotland, there are shared Transmission and Distribution control centres and typically a Transmission Authorised Engineer may act as support for a Distribution Control Engineer, meaning effective minimum staffing is two Distribution control engineers and one further Transmission Control Engineer holding an authorisation to switch distribution network equipment.

Typical roles which are common across DNOs are: Control Room Managers, Senior Control Engineer, Control Room Liaison Engineers, Distribution Control Engineers and Planning Engineers [13].

While it is anticipated that initial network segregation should be possible by the control staff on shift, more complex procedures during later phases of the restoration require additional personnel. Dependent upon the level of scripted switching relied on for Black Start, which is variable across DNOs, the requirements are between one and three DCEs per LJRP.

The Distribution Control Engineer (DCE) will be responsible for:

- following the instructions of the Transmission Control Engineer to create dead zones on the SCADA system
- restoring customers at a primary substation level once grid supply points are energised, with the assistance of the Load Management Engineer
- obtaining and understanding the state of the distribution network given that under frequency protection will have operated and there is potential Load Transfer Schemes may have operated.

Should a shortfall in generating capacity become evident the DCE would initiate power rationing to non-critical national infrastructure (CNI) customers, again with the assistance of the Load Management Engineer.

Support staff

It is not anticipated that there would be a heavy reliance on site engineers due to remote telemetry. However, to achieve resourcing of these roles and additional control engineers needed to support the event, DNOs operate a text messaging service which alerts staff that an event has occurred with instruction to attend site. Further mitigations to improve communication by control staff include use of priority sim cards to alleviate congestion, satellite phones for key staff, requirements for a landline telephone and use of airwave communications but this is not consistent across the industry. All DNOs assume that this infrastructure is not power resilient for long enough to assure communication to key people, hence have policies for self-starting during a suspected event [12].

The number of field staff varies significantly between distribution licence areas and across different voltage levels, different authorisations are held. Strategic substations would have key personnel assigned a self-starting policy but may rely on further communications using resilient communications available at drop-points or these substations to enable more remote sites to be resourced. [10]

Furthermore, the network is expected to be in an abnormal condition with multiple remote terminal units and communications failures inhibiting the DCE's awareness of the network status. The DCE shall contact the relevant engineer/help desk responsible for the telecommunications network, SCADA Central Systems and SCADA substation apparatus and request they immediately attend a suitable location with generator back-up where they can access the SCADA systems; thus allowing them to identify and assess SCADA related faults affecting the network.

Skills requirement

The overall role of the DNO during a Black Start is to facilitate the connection of demand to the transmission system. This is particularly important during the block loading phase where an open line with the provider is established to connect and disconnect small loads to stabilise the generator. This requires segregation of the network into small demand groups and isolation of any interconnected grid supply points (GSP) and bulk supply points (BSP) for later phases of restoration.

The specific roles are different between DNOs but based upon the required processes, the following capabilities must exist:

Senior Control Engineer: Implement an LJRP, organise and lead the control room, control room liaison with senior leaders, develop resourcing rotas.

Load Management Engineer: Frequency management, select primary feeders to be re-energised and provide suitable demand, estimate expected demand at each primary feeder. Responsible for block loading the generator.

Distribution Control Engineer: Establish initial state of distribution network post black out, Distribution Network Authorised Switching Engineer, support Load Management Engineer, contact SCADA Engineers to establish communication system faults, categorise fault types. Must be capable of segregating the network into block loads with the Load Management Engineer function. [7]

Training processes

All DNO control staff must undergo an authorisation to perform their specific role outside of Black Start conditions, giving them the skills and knowledge to support a Black Start. However, there is not a consistent approach to Black Start training across DNOs. Desktop exercises, knowledge shares, joint exercises with power stations and seminars are all methods used by DNOs to reinforce the knowledge from the authorisation training and typically recur yearly. DNOs each have varying levels of simulator training capability and are able to conduct their own training through these systems.

Most DNOs have nominated Black Start leads who assure this capability across the control room, often attending NGESO led training events or workshops and knowledge sharing with the wider team upon their return.

Scottish TOs are involved in the NGESO annual training event in their role as Transmission Owner but given their shared role as a DNO they knowledge share on the return. Similar arrangements are beginning to be developed by NGESO across all DNOs with nominated representatives being invited to join desktop exercise training, but this is currently limited to simulations of NGESO's internal systems rather than the interfaces they would use to directly manage the event. In addition there is a requirement for a joint training event once every eight years per LJRP within their licence area [12] [13] [14] [15].

Black Start service providers

Table 7.5
Provider personnel summary

Categories	Key details
Control staff	Typically, three control engineers
Support staff	Additional site technicians Electrical & Mechanical Engineering Manager/Lead
Skill requirements	Knowledge of start-up/shutdown procedure Understanding of Black Start auxiliaries HSE critical author to change Black Start processes
Training processes	Rigorous Authorisation Process Specific Black Start element Experience of unplanned start-up/shutdown Black Start tests Octennial LJRP joint exercise

Control staff
There are no specific organisational roles specified for a Black Start service provider. However, each provider must be able to deliver the station's Black Start process under the lowest staffing conditions (including out-of-hours shift) within the contracted timeframe to achieve target voltage at the transmission system busbar.

For a typical Black Start service provider, a minimum of three control staff are available, although this number may be higher in normal operations. Additional day staff may be called in to provide further support but are not relied upon to deliver Black Start within the allowed timeframe.

The specific control room roles are typically a Senior Control Engineer or Shift Manager and two control engineers [16].

Support staff
As Black Start service providers are typically large power stations, they have associated support staff, frequently based on site or shared across a fleet of units in the case of some portfolio operators. This typically includes a site mechanical and electrical engineering manager, multiple site technicians and several shift teams who would be on site during normal weekday hours. This support staff cannot be relied upon to enact the initial process of energisation but due to the untypical operating conditions, it is expected that the shift manager would determine appropriate resourcing and call further people to attend if needed. SMS alert and airwave radio systems or self-starting policies are all methods which can be used to alert additional staff of the incident and get site attendance [16].

Skill requirements
In its overall role as provider of the voltage source and power source, under the initial stages of restoration the provider is responsible for all internal start-up procedures and direct liaison with the DNO (or in Scotland, the relevant TO) to stabilise the unit. In later stages of the restoration, it must provide voltage control and frequency control across the Power Island in parallel operation with multiple energy resources.

Each provider has different control engineering competencies included in their authorisation and should receive specific Black Start training as part of this process where contracted.

A typical requirement is control room authorised engineers with an understanding of all normal generator operations and specific knowledge of the plant's Black Start procedure. The control engineers must be skilled and experienced at start-up and shutdown operations. They must have capability to manually fix/over-ride control settings on plant where they cannot be remotely operated or monitored. They must have a strong knowledge and/or access to the power station circuitry design and understand their plant's Black Start capabilities.

As a HSE critical task only specific highly experienced people, who have undergone HSE critical author training, are able to change any of the internal process steps or versions. [16]

Training processes
Typically, it is a one-year process to authorise a power station control engineer. This would include an element of Black Start training at providers which is an expansion on start-up and shutdown procedures. This authorisation develops all the specific skills required to manage a Black Start.

To develop an understanding of the processes required, a training control room engineer can be a 'viewing' participant under a Black Start test. Trip-induced blackouts provide practical training and approximately weekly (dependant on market conditions) start-up/shutdown tests are used to reinforce the understanding of these processes [16].

DERs

Table 7.6
DER personnel summary

Categories	Key details
Control staff	Varies depending on resource type
Support staff	Varies depending on resource type
Skill requirements	Limited existing capability
Training processes	No Black Start training

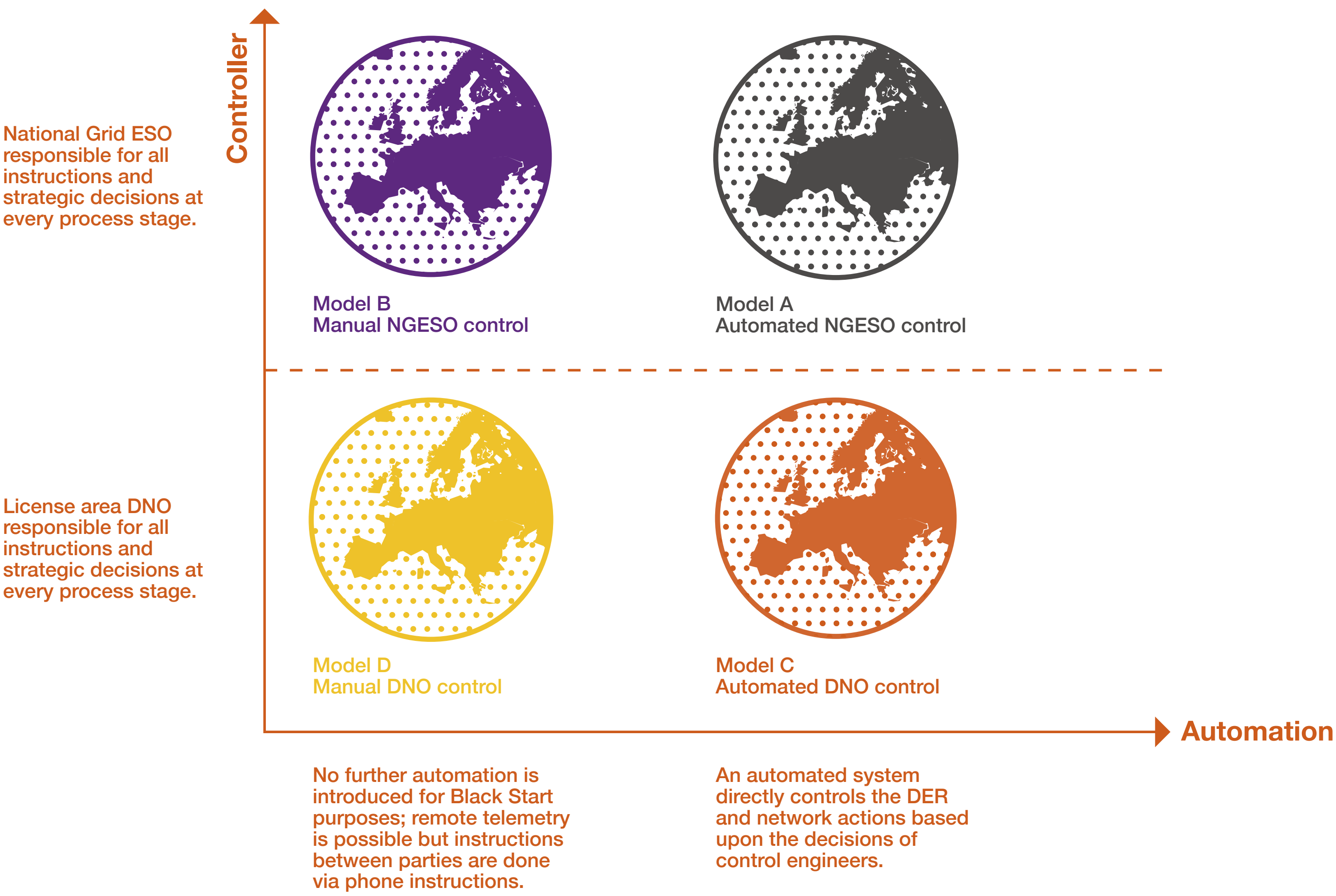
8. Organisational models

In order to future-proof our organisational analysis against the rapidly evolving DSO models, we have defined 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 will enable the design phase to refine these into organisational structures.

8.1 Introduction

The set of models developed by Distributed ReStart illustrate some extreme cases for incorporation of DER into a Black Start. The models have been created to help us explore the impact of differing control options and levels of automation rather than as proposed solutions.

Figure 8.1
The models analysed represent a set of discrete options for the control of a Distributed ReStart process, through the design phases the responsibility may differ between restoration phases and some intermediary level of automation such as support tools, scripting or DRZ controllers may be used in place of automatic control of network and machines.



8.2 Process

In all models, common phases of restoration are used to keep consistency of analysis. The basic process outlined in this subsection enables a Power Island to be grown on the distribution network. To distinguish between this and a transmission Power Island, we call this a distributed restoration zone (DRZ). The outcomes of our power engineering design phase and further organisational systems work will refine the details for this restoration process [17].

Furthermore, across all models we maintain the assumption that this service is run in parallel with conventional Black Start LJRPs. We anticipate a phased approach to roll-out which will retain the economic and technical benefits of a diverse portfolio of providers.

Stabilisation

The initial step in establishing a DRZ is to achieve stability of the first DER. Initially, this would mean incrementally loading a DER using flexible demand, then potentially switching to normal feeder demand after the minimum stable generation (MSG) is met. It is anticipated that matching forecast cold load pick-up with a corresponding reduction of flexible demand would manage the power imbalance to small demand changes the DER is capable of meeting.

Distribution island growth

Distribution island growth would follow the stabilisation phase. Using the reactive power capability of the DER, the distribution network would be energised to the point of connection for an additional generator. Incremental iteration of this phase could occur until the skeleton distribution island reaches a stable point with sufficient reactive power capability to energise the wider distribution network or transmission network.

When the Power Island is sufficiently large enough, substantial frequency response provision could allow for DERs that are not directly controlled as part of the DRZ to be incorporated.

Transmission energisation

The DRZ energises through voltage levels up to the point of a transmission grid supply point (GSP). At this point, through direct liaison with the TO, the distribution island can begin to establish a voltage at transmission level. Instructions issued to increase or decrease DRZ output through demand and generation management would facilitate this wider network growth. From the point of energisation, the DRZ acts as a virtual Black Start service provider able to supply demand at other GSPs and aid wider transmission energisation.

8.3 Models

The models selected for analysis represent the extreme possibilities for the organisation driving and controlling the restoration process in a distribution Power Island and for the level of automation applied. In the design phase, these models will be 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.

- **Model A**, NGESO is the DRZ controller, fully automated instructions are issued.
- **Model B**, NGESO is the DRZ controller using no additional automation to issue instructions.
- **Model C**, DNOs are the DRZ controllers for their network area and use automation to issue instructions.
- **Model D**, DNOs are the DRZ controllers for their network area using no additional automation to issue instructions.

Additional models identified but not pursued further include:

DER led, this has been dismissed because of the liability concerns associated with allowing a DER to switch distribution equipment. Furthermore, the lack of pre-existing network management capability makes them less suited to this role than alternatives identified above.

Autonomous DNO control, this has been dismissed as engagement with DNOs through the Networks Round Table event, individual DNO survey responses and DNO Black Start training events has demonstrated that there is a need for a national controlling body [12] [15]. This is assumed to remain as NGESO to enable parallel operation with the existing process.

Automation with no human input, this has been dismissed as stakeholder engagement with DNO control engineers and ESO control engineers has confirmed that any system used for Black Start would need to form part of normal working practices [12] [14] [15]. Full automation of control rooms for normal working practice is outside the scope of this project so has not been considered further.

To assess the four models, the same criteria are applied as was used in section 7. This includes analysis by organisation of:

- control staff requirements
- support staff requirements
- skill requirements
- training processes.

Furthermore, in order to ensure the design aligns with requirements, additional criteria have been applied:

- meets Black Start needs
- ease of implementation
- flexibility for the future
- alignment with wider industry changes.

The assessment assigns a status according to table 8.1.

Table 8.1
Criteria scoring for models

Status	Key details
Green	No anticipated change or minor changes possible
Amber	Moderate change required
Red	Large to insurmountable change required

Furthermore, all models are assigned assumptions that will be tested in the design phases. These assumptions are required to allow for baseline analysis and where disproven will result in different organisational impacts but will not invalidate the model.

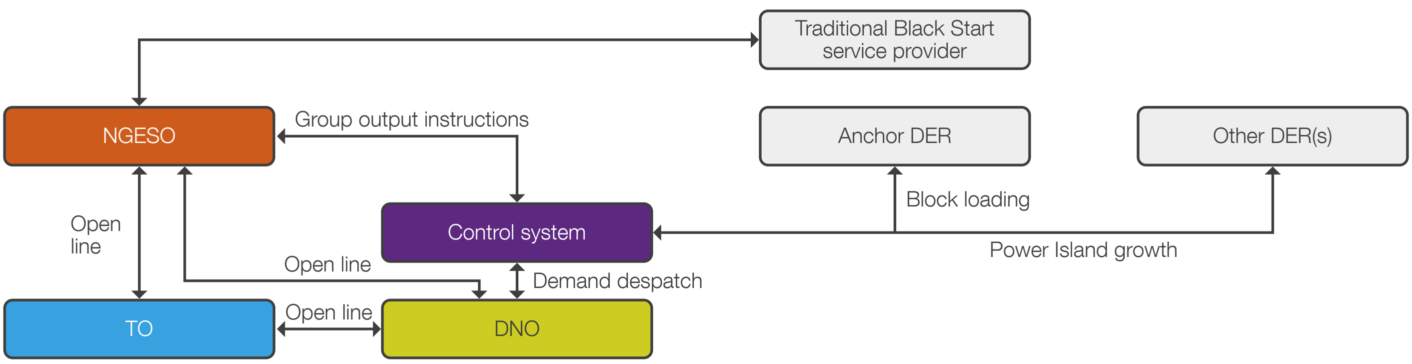
8.4 Model A (Automated NGESO Control)

The first future model assumes a single control and implementation function led by the system operator. In this scenario, NGESO control all aspects of a distributed restoration zone (DRZ) utilising an automated system to switch and despatch DNO & DER equipment as required. This is selected as an option with the highest level of automation and the least number of interfaces involved in the control. To enable this model, the following assumptions are required:

- Regardless of the controller capability, a Human Machine Interface is required.
- The Human Machine Interface would provide visual identification of energised circuits and DRZ frequency, voltage, currents, DER parameters, flags power system synchroniser breakers and shows GSP/feeder loading/cold load pick-up and protection systems.
- The automated control system would be capable of accepting instructions from NGESO for service export at the transmission network interface, inclusive of but not limited to: reactive power import and export, frequency response and real power export.
- The initial point of interconnection between distribution networks and transmission networks would be isolated to a single grid supply point (GSP) per DRZ to prevent very complex transmission switching and isolation.
- The DNO and DER allow for automatic interaction between the controller unit and their assets.
- Automation is limited to the DNO network and a transmission restoration strategy is still required to facilitate transmission network growth and interconnection.
- The DNO can provide flexible demand through automation of discrete small loads; examples include, battery energy and storage systems (BESS), load-banks or highly segregated network areas.
- Any automated system must be integrated into standard NGESO activities to achieve the required level of familiarity.

8.4.1 Companies

Figure 8.2
Diagram showing the communications which occur between parties to facilitate an automated NGESO controlled Black Start in parallel with existing LJRPs



The communications structure outlined in figure 8.2 shows that in this model National Grid Electricity System Operator is responsible for the overall Black Start process, establishing and sustaining control of the DRZ through a control system and direct liaison with the relevant Transmission Owners and distribution network owners.

The TO has an open telecommunications line with NGESO and the DNO for which the DRZ and any LJRPs apply. This allows for operational switching instructions to be both received and for network energisation to be directly monitored with respect to outward energisation from a GSP associated with the DRZ or energisation to a demand supplying GSP.

The DNO would interface with the TO, assessing network conditions and likely energisation routes. An open line with NGESO would communicate strategy and coordinate LJRP block load provision from conventional plant and from any DRZs which are transmission connected. It would also monitor the direct switching from the controller unit and abort any instructed processes if required.

All DERs included in the DRZ would directly interface with the control system and change their outputs as required for overall restoration stability per NGESO instructions to the group.

8.4.2 National Grid Electricity System Operator

Table 8.1
Model A – NGESO organisational impact summary

Categories	Key details
Control staff	Moderate increase in resource requirements which scales as multiple DRZs are run in parallel.
Support staff	Moderate increase in resource requirements. Increased assurance complexity but with possibility to automate some of the assurance process. Increased demands on Systems Support teams to keep DNO model and automated system updated.
Skill requirements	Additional knowledge needed to manage DNO networks. Additional capability needed to manage and monitor an automated system.
Training processes	No fundamental changes needed to training practices, but additional content required.

8.4.3 Transmission Owners

Table 8.2
Model A – TO organisational impact summary

Categories	Key details
Control staff	Potential reduction in Scottish TO obligations to operate as a strategic controller. No expected Transmission Operations changes.
Support staff	No anticipated change.
Skill requirements	No anticipated change.
Training processes	No anticipated change.

8.4.4 Distribution Network Operators

Table 8.3
Model A – DNO organisational impact summary

Categories	Key details
Control staff	Potential increase in resource requirements due to further data validation and monitoring roles when run in parallel with the existing process.
Support staff	No anticipated change.
Skill requirements	Broadly consistent skill requirements with further capability to abort the automated system and assure data quality. More people required to be trained in Black Start.
Training processes	A means to train DNO staff on these new roles in conjunction with NGESO would be needed.

8.4.5 Distributed energy resources

Table 8.4
Model A – DER organisational impact summary

Categories	Key details
Control staff	Where direct control is enabled, resourcing impact is minimal. Where this is not achieved a minimum dedicated staff level would be needed.
Support staff	No anticipated support staff requirements.
Skill requirements	Minimum additional requirements to enable abort processes where direct control is agreed. Otherwise bespoke Black Start procedural knowledge is required.
Training processes	No anticipated change where direct control is agreed. A full new authorisation process may be needed if enacting a Black Start process.

8.4.6 Additional criteria

Table 8.5
Model A – additional criteria summary

Categories	Key details
Meets Black Start needs	The Black Start needs are mostly met but full automation may lose flexibility which is a key part of the restoration requirements.
Ease of implementation	This is the most complex model to establish. It involves a full redesign of the DNO control model. A single solution must be capable of managing multiple network types and interface points from the onset and be capable of extension across GB from the onset.
Flexibility for the future	Each new DRZ would require a significant quantity of set-up work inclusive of physical control infrastructure across wider DNO network areas. Reduces capability to enhance competition or ensure diverse supply options as a result.
Alignment with wider industry change	Most current innovation projects use independent DSOs, with ESO services requested at a transmission interface point. This does not align with the general industry shift towards DNOs becoming DSOs.

8.5 Model B (Manual NGESO control)

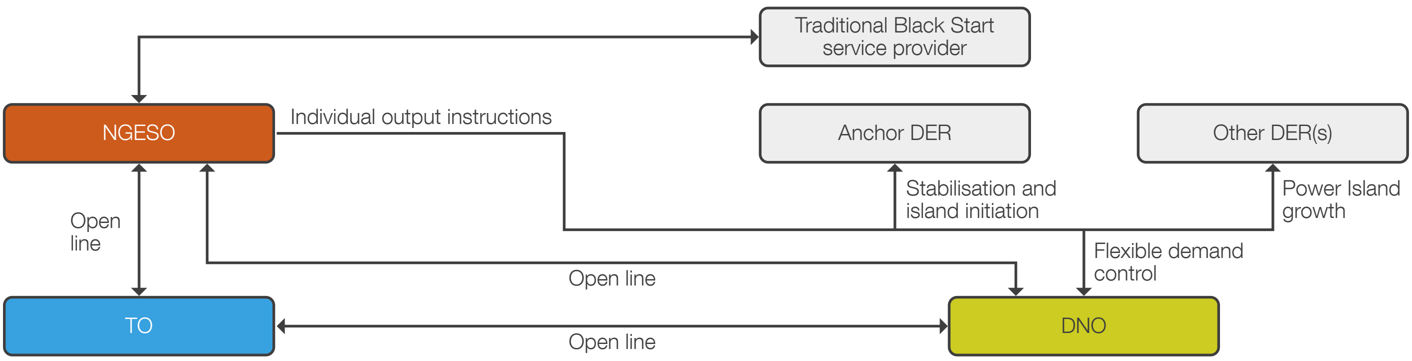
In model B, NGESO controls all aspects of a DER led restart, giving instructions on which sites to energise, how and what routes to follow. NGESO would require full visibility of the DNO networks to instruct manual switching of the DNO and provider. This reduces the number of interfaces but has the minimum level of automation possible as everything is switched and instructed manually.

To facilitate this model, the following assumptions are made:

- NGESO are given full visibility of the DNO network, its state of energisation and the Power Island frequency.
- DNOs can provide flexible demand, either through the network, through load-banks or through BESS.
- The point of interconnection between distribution networks and transmission networks would be isolated to a single grid supply point (GSP) per DRZ.
- Manual Black Start procedures for a DER plant can be managed using existing staff arrangements similarly to a traditional provider.
- Scottish TOs do not become DRZ controllers in this model.

8.5.1 Companies

Figure 8.3
Diagram showing the communications which occur between parties to facilitate a manual NGESO controlled Black Start in parallel with existing LJRPs



NGESO would be in overall control of the Black Start event, interfacing directly with the anchor DER to gather data and instruct initiation of the DRZ. It also would interface directly with the DNO to coordinate flexible demand provision and with the TO to provide transmission network switching instructions. To achieve this demand control, an open line would be needed with the DNO and the TO.

The TO would require an open telecommunications line with NGESO and the DNO for which the DRZ and any LJRPs apply following the existing communications protocol. This allows for operational switching instructions to be received and for network energisation to be directly monitored with respect to both outward energisation from a DRZ or energisation to a demand supplying GSP in an overlaying LJRP.

The DNO would interface with the TO, assessing network conditions and likely energisation routes. It would also be involved in the direct block loading of anchor DERs and other DERs through segregation of its network and through control of flexible demand.

All DERs included in the DRZ would directly interface with the ENCC receiving instructions on when to enact the DRZ and subsequent modes of operation. Furthermore, it would interface with the DNO during its own block loading phase.

8.5.2 National Grid Electricity System Operator

Table 8.6
Model B – NGESO organisational impact summary

Categories	Key details
Control staff	Each DRZ would require multiple generators to give a similar service level to a conventional provider. This leads to a large increase in staff requirements in this organisation. This increase in staff requirements would not enable multiple DRZs to be run in conjunction Greatest resourcing requirements for NGESO of any model reviewed.
Support staff	Moderate increase in resource requirements. Increased assurance complexity. Increased demands on systems support teams to keep DNO models updated. However, lesser requirements than model A.
Skill requirements	Visibility of DNO networks and an understanding of how to interpret this data is needed. A thorough awareness and understanding of distribution network operations would need to be developed in addition to the present skills capability.
Training processes	Significantly greater numbers of people would need to be trained which may be unmanageable with existing facilities and authorisation processes.

8.5.3 Transmission Owners

Table 8.7
Model B – TO organisational impact summary

Categories	Key details
Control staff	For England and Wales transmission no change is anticipated. For Scotland depending on process design, acting as the DRZ controller would expedite speed of restoration but have very large resourcing requirements. Assumption that NGESO does not devolve this role to Scottish TOs is therefore applied. Without this assumption it becomes a red status.
Support staff	No anticipated increase in resourcing.
Skill requirements	No anticipated resource changes. For Scotland if assumption is invalidated this becomes Amber status reflective of NGESO.
Training processes	No specific requirement for changes in training processes but may require involvement of DNOs in biennial exercises.

8.5.4 Distribution Network Operators

Table 8.8
Model B – DNO organisational impact summary

Categories	Key details
Control staff	Moderate impact on staff resourcing but lesser than model C and model D. Requirements for additional Distribution Control Engineers to act as Load Management Engineers switching the flexible demand.
Support staff	Potential additional requirements for field staff.
Skill requirements	Specific process knowledge. Enhanced load management capability to facilitate generator stabilisation.
Training processes	A common method for training DNOs would be needed. The current octennial standardised exercise would be insufficient.

8.5.5 Distributed energy resources

Table 8.9
Model B – DER organisational impact summary

Categories	Key details
Control staff	Likely to require manned sites if contracted where the DER is a provider. Overall impact varies from none to significant dependant on existing operational method used.
Support staff	No anticipated impact.
Skill requirements	Depending on current control structure, change varies from minor to significant. A requirement for further start-up/shutdown process knowledge with specific understanding of Black Start developed.
Training processes	A full new authorisation process including Black Start should be developed, specific to each provider's requirement.

8.5.6 Additional criteria

Table 8.10
Model B – additional criteria summary

Categories	Key details
Meets Black Start needs	A single organisation in control of a manual process would create a bottleneck increasing restoration timescales. A key objective of this project is to enable enhanced restoration time. Hence, this model reduces the value of any outputs.
Ease of implementation	The likely systems requirements to manage this model are substantially lesser than for model A. A challenge with this approach would be recruitment of enough capable control engineers and the timeframes required to authorise these personnel. Furthermore, to implement this as part of standard processes it is a significant shift in the role of NGESO which may be objectionable for DNOs.
Flexibility for the future	Through having a fully manual process, ultimate flexibility is retained for control operators during the event. The capability to automate inefficient process components building from this baseline gives an enhanced potential to meet changing system needs.
Alignment with wider industry change	The ENA are progressing with a case study in which NGESO instruct DNOs but do not actively switch the network which is like this model. However, this is different to most innovation project solutions so alignment is limited.

8.6 Model C (Automated DNO control)

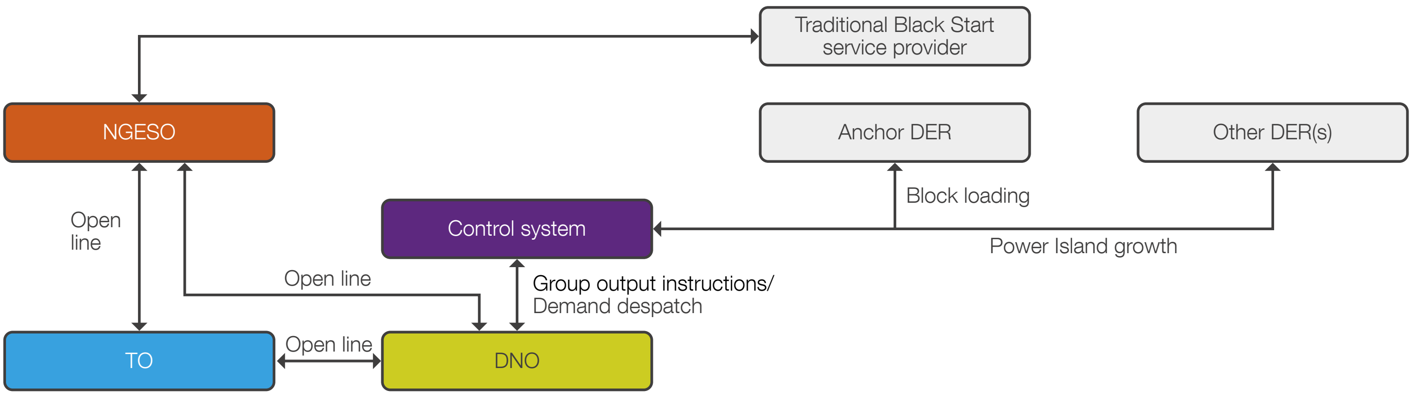
In model C, the NGESO role is limited to instructing DNO actions after energisation of the MITS; after this point, the Power Island has a separate transmission restoration plan and the DRZ acts as a power source. To achieve transmission level energisation and power, DNOs would have access to an automated system for the management of Power Island growth and operation, whereas the focus of NGESO would remain on restoration of the MITS and overall strategy for GB.

To enable this model, the following assumptions are required:

- Regardless of the controller capability, a Human Machine Interface is required.
- The Human Machine Interface would provide visual identification of energised circuits, DRZ frequency, voltage, currents, DER parameters, Power System Synchroniser Breakers, feeder loading, estimates for cold load pick-up, frequency deviation on energisation/de-energisation and protection systems.
- The automated control system would be capable of accepting instructions from the relevant DNO to provide a service from the GSP interconnection to the transmission system, inclusive of but not limited to: reactive power import and export, frequency response and real power export.
- The export point at transmission level would be isolated to a single transmission substation per group.
- The DER allow for automatic interaction between a controller unit and their assets.
- The behaviour and capability at MITS of a DRZ is equivalent to that of a conventional Black Start service provider of equivalent MVA size if being used to energise the MITS.

8.6.1 Companies

Figure 8.4
Diagram showing the communications which occur between parties to facilitate an automated DNO controlled Black Start in parallel with existing LJRPs



NGESO would focus only on the national Black Start strategy in model C. The only interface change for NGESO is direct communications with the DNO being opened, needed because the DNO in control of a DRZ would act as a virtual Black Start service provider after energisation of the MITS.

The TO would experience no change in interfaces except that it would no longer need to relay instructions from NGESO to the DNO.

The DNO would have access to an automated system which manages Power Island growth and operation. Any input required would come directly from the DNO in the form of electronic instructions and scripted processes. A new direct interface with NGESO would be opened to enable the same control level post transmission system energisation as exists in a current Black Start service provider.

DERs would only have an interface via the automated system. It is only anticipated that abort functionality or indication of availability would be enabled for the DER.

8.6.2 National Grid Electricity System Operator

Table 8.11
Model C – NGESO organisational impact summary

Categories	Key details
Control staff	No anticipated change in resourcing.
Support staff	More complex assurance process but potentially delegated to DNOs in control or relying on automated assurance processes.
Skill requirements	No anticipated change in skill requirements.
Training processes	There may be a greater requirement to hold joint training exercises beyond the octennial LJRP exercise.

8.6.3 Transmission Owners

Table 8.12
Model C – TO organisational impact summary

Categories	Key details
Control staff	No anticipated change in resourcing Potential to utilise existing Scottish transmission Control Engineer skills in generation despatch to support DNOs.
Support staff	No anticipated change to Transmission Owners.
Skill requirements	Potentially more complex switching requirements but no further skill requirements.
Training processes	No anticipated change in training Potential to involve DNOs in biennial training.

8.6.4 Distribution Network Operators

Table 8.13
Model C – DNO organisational impact summary

Categories	Key details
Control staff	Moderate increase in control staff requirements. Increased number of Distribution Control Engineers to handle increased distribution network monitoring requirements whilst concurrently operating an LJRP. Additional DCEs required to facilitate generator despatch monitoring requirements.
Support staff	Depending on the outcomes of the design phase for procurement and compliance, procurement and assurance obligations could shift to DNOs for their licence area. No roles to facilitate this currently exist within these organisations. Potential to automate some of these assurance activities.
Skill requirements	Specific knowledge of operation of the automated system. Enhanced voltage and frequency control capability. Specific generator (DER) operational knowledge for monitoring.
Training processes	Overall, training processes should align with NGESO's current practice. This would require significant additional training requirements but is unlikely to be so onerous as in model D.

8.6.5 Distributed energy resources

Table 8.14
Model C – DER organisational impact summary

Categories	Key details (same as model A)
Control staff	Where direct control is enabled, resourcing impact is minimal. Where this is not achieved a minimum dedicated staff level would be needed.
Support staff	No anticipated support staff requirements.
Skill requirements	Minimum additional requirements to enable abort processes where direct control is agreed. Otherwise bespoke Black Start procedural knowledge is required.
Training processes	No anticipated change where direct control is agreed. A full new authorisation process may be needed if enacting a Black Start process.

8.6.6 Additional criteria

Table 8.15
Model C – additional criteria summary

Categories	Key details
Meets Black Start needs	An automated system has inherent redundancy from multiple geographically dispersed DNO systems. This aligns with desire for enhanced restoration timescales and geographically ambivalent prioritisation for demand restoration.
Ease of implementation	Very complex process to roll out an automated system. However, less onerous than model A because of the potential for phased roll-out and current data owners becoming system owners.
Flexibility for the future	Each new DRZ would require a significant quantity of set-up work inclusive of physical control infrastructure across wider DNO network areas. Reduces capability to enhance competition or ensure diverse supply options as a result.
Alignment with wider industry change	Broad alignment with the ENA worlds B and D for future DSO arrangements depending on the commercial arrangements. Broad alignment with current innovation projects. Level of automation is beyond most models but consistent with the general industry trend.

8.7 Model D (Manual DNO control)

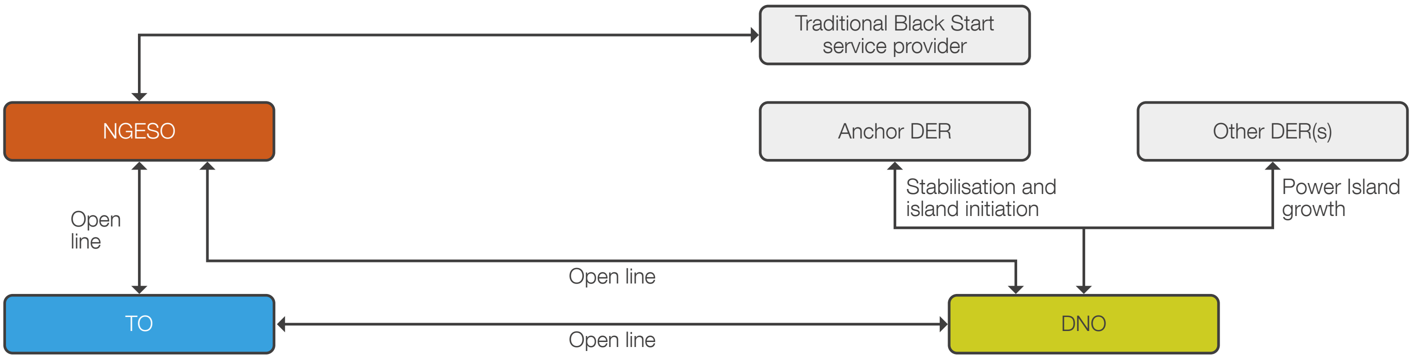
In model D, the NGESO role remains focused on transmission restoration whilst DNOs may independently manage DRZs. After Power Island growth has facilitated energisation of the transmission system, the DRZ acts in a similar manner to an existing Black Start service provider and requires an associated transmission restoration strategy. DNOs would manually manage Power Island growth and operation, issuing controls to DERs which regulate output at the transmission network interconnection point.

To enable this model, the following assumptions are required:

- The export point at transmission level would be isolated to a single transmission substation per group
- The behaviour and capability at transmission level of a DRZ is equivalent to that of a conventional Black Start service provider of equivalent MVA size where being used for transmission restoration.
- Flexible resources are available in the DRZ either through the capabilities of the DER such as BESS or with supplementary resources like load banks.

8.7.1 Companies

Figure 8.5
Diagram showing the communications which occur between parties to facilitate a manual DNO controlled Black Start in parallel with existing LJRPs



NGESO maintains overall strategic control of the Black Start process and has the same interface points as the existing process. It has an open line with the TOs and directly contacts traditional Black Start service providers to enact their plans. There is an existing open line to the DNO which acts similarly to the service provider under this version of a DRZ.

The TO is responsible for all transmission operational switching to facilitate the conventional LJRP and any outward DRZ transmission energisation. An open line with NGESO and the DNOs is established to enable this.

The DNO is responsible for all distribution network switching, the actions required include: Stabilising the initial generator providing small blocks of DNO demand from segregated bits of network. Furthermore, it must control a flexible demand unit to reduce the size of block the generator is subjected to.

In addition, the information gathering process would need to be provided by the DNO across all DERs in the network area to establish capability to support DRZ growth. Through management of the flexible demand and real network demand, the group frequency and voltage should be maintained within acceptable limits to prevent DRZ collapse during the continual Power Island growth.

The anchor and other DERs would both be responsible for direct management of their site upon instruction from the DNO. This would be their only interface point during a DRZ. Post LJRP it is possible that this interface would move to NGESO if it directly provides services under existing frameworks.

8.7.2 National Grid Electricity System Operator

Table 8.16
Model D – NGESO organisational impact summary

Categories	Key details
Control staff	No significant change in resourcing for the ENCC.
Support staff	Overall procurement and assurance processes would be more complex. Depending on outcomes of the procurement and compliance design phase report, this may expand the current role significantly.
Skill requirements	No anticipated change in skills required.
Training processes	Likely to require inclusion of DNOs in biennial exercises.

8.7.3 Transmission Owners

Table 8.17
Model D – TO organisational impact summary

Categories	Key details
Control staff	No anticipated change in resource requirements.
Support staff	No anticipated change in resource requirements.
Skill requirements	Potential for more complex switching actions but no new skill requirements. Some transferrable skills exist in Scottish TOs which would be needed in DNOs.
Training processes	Likely to require inclusion of DNOs in biennial exercises.

8.7.4 Distribution Network Operators

Table 8.18
Model D – DNO organisational impact summary

Categories	Key details
Control staff	Significant increase in workload for the DNO requiring multiple additional DCEs. Limited complexity per person allocated to demand and generation management. Some confidence from DNOs that current resources may facilitate a single DRZ. Most onerous overall DNO resourcing requirements.
Support staff	Depending on the outcomes of the design phase for procurement and compliance, procurement and assurance obligations could shift to DNOs. No roles to facilitate this currently exist. Slightly more onerous than model C due to lesser possibility for automation.
Skill requirements	Enhanced voltage and frequency control capability Specific understanding of the behaviours of DERs included within the DRZs controlled by this DNO Energy management and generation despatch under Black Start conditions. Demand forecasting within the 'energy management' function. DRZ/ANM/LMS control/understanding.
Training processes	Upskilling further Distribution Control Engineers to be capable of acting as generation dispatch engineers for control of DRZ growth. To achieve the new skill requirements, this would require significant investment in training to align this with the present NGESO training type and frequency. This would require enhanced training capability and potentially further training facilities bespoke to the DNOs existing systems.

8.7.5 Distributed energy resources

Table 8.19
Model D – DER organisational impact summary

Categories	Key details (same as model B)
Control staff	Likely to require manned sites if contracted where the DER is a provider. Overall impact varies from none to significant dependant on existing operational method used.
Support staff	No anticipated impact.
Skill requirements	Depending on current control structure, change varies from minor to significant. A requirement for further start-up/shutdown process knowledge with specific understanding of Black Start developed.
Training processes	A full new authorisation process including Black Start should be developed, specific to each provider's requirement.

8.7.6 Additional criteria

Table 8.20
Model D – additional criteria summary

Categories	Key details
Meets Black Start needs	Multiple DRZ controllers geographically dispersed would lead to faster regionalised restoration timescales than model B but slower restoration timescales than models A and C. It is better able to be run as a parallel function to the existing LJRP than models A and B which also aligns with current capabilities. However, it is unlikely to lead to a faster restoration timeframe than existing LJRPs without significant additional resourcing in DNOs.
Ease of implementation	Model D is the easiest to implement of all models considered. However, it still represents a significant change from existing processes and responsibilities. There would be limited impact on control system requirements and DNOs have indicated a baseline capability to manage a single DRZ.
Flexibility for the future	Through having a fully manual process, ultimate flexibility is retained for control operators during the event. The capability to automate inefficient process components building from this baseline gives an enhanced potential to meet changing system needs.
Alignment with wider industry change	Broad alignment with the ENA worlds B and D for future DSO arrangements depending on the commercial arrangements. Lesser automation than most innovation projects but consistent with current industry processes.

9. Organisational summary

At this stage of the project, no specific solution is proposed. From the development of a set of models, we have begun to identify the benefits, difficulties and risks of alternative Black Start operational options and our initial findings are summarised in table 9.1.

In the design phase, the project will take this analysis further to develop a detailed process map with clear demarcation of potential process ownership together with the associated roles and training requirements. Where appropriate, we will use some cost benefit analysis to determine the points at which it is beneficial to use additional tools or automation to enable faster, more accurate or efficient restoration.

Table 9.1
Summary table of outcomes from organisational analysis as described in section 8, RAG criteria defined in table 8.

Category	Organisation	Outcomes of organisational analysis				
		Present capability	Model A	Model B	Model C	Model D
Control staff	NGESO	23 control engineers				
	TOs	2 to 5 control engineers under minimum staffing				
	DNOs	2 control engineers minimum				
	Providers/DERs	2 control engineers minimum				
Support staff	NGESO	Dedicated support teams				
	TOs	Reliant on policy for additional resourcing				
	DNOs	Reliant on policy for additional resourcing				
	Providers/DERs	Do not rely on additional resource				
Skill requirements	NGESO	Energy, strategy, transmission control				
	TOs	Transmission control				
	DNOs	Distribution control				
	Providers/DERs	Start-up/Shutdown				
Training processes	NGESO	Yearly training				
	TOs	Biennial training				
	DNOs	Yearly knowledge share				
	Providers/DERs	During authorisation and assurance				
Supplementary criteria	Meets Black Start needs	Present needs met				
	Ease of Implementation	Functional process exists				
	Flexibility for the future	Threatened by closure of large conventional providers				
	Alignment with wider industry change	Does not fit the themes of decentralisation, decarbonisation or digitisation				

Distributed ReStart

Operational Telecommunications

10. Operational Telecommunications Introduction

Operational Telecommunications play a vital role in the safe, reliable and efficient operation of the transmission and distribution network. Our review has covered all aspects through engagement with a wide variety of stakeholders.

10.1 Introduction

Operational Telecommunications comprise of the infrastructure to deliver voice and data, tele-protection and the systems to monitor and control the power grid, potentially including enhanced situational awareness to the control room operators. They play a vital role in the safe, reliable and efficient operation of the transmission and distribution networks. Utilities that provide critical national infrastructure sometimes operate separate telecommunication networks (Operational Telecommunications) for core operational activities from normal non-operational business as usual activities. The operational network is configured to meet specific standards on confidentiality, integrity and availability requirements.

At present, a relatively small number of Black Start participants utilise dedicated fibre links for Operational Telecommunications (voice and data). Introducing DER into a Black Start process could lead to a considerable increase in the volume of stakeholders; data points and the number and types of potential Operational Telecommunications (e.g. microwave, satellite).

10.2 Approach

We begin our analysis of Operational Telecommunications by reviewing the current telecommunication infrastructure and systems used to deliver the 'traditional' transmission-led Black Start. This review is based on stakeholder engagement with the relevant participants, through the use of questionnaires, workshops and bilateral meetings.

This is followed (in section 12) by a review of the various options to deliver the telecommunication capability to support Black Start from DERs, where we present alternatives to deliver new infrastructure and to extend the current infrastructure.

The systems potentially required for managing Distributed ReStart are discussed in section 13.

In section 14, we discuss the impact and role of cyber security to Operational Telecommunications and the standards to which utilities who operate CNI networks are required to work towards.

Finally, in section 15 we present the technical details of case studies of two trial sites from SP Distribution (SPD) and SP Manweb (SPM) networks looking at the telecommunications infrastructure used to deliver Operational Telecommunications to the sites.

11. Existing Operational Telecommunications

Current Operational Telecommunications have been reviewed. The assessment conducted included voice and data communication infrastructure, the technologies currently in place and the systems used.

11.1 Current Operational Telecommunications

11.1.1 Introduction

In this section, we present the highlights of our assessment of the current Operational Telecommunications. The assessment conducted included voice and data communication infrastructure, the technologies currently in place and the systems used by NGESO, NGET and the DNOs.

11.1.2 Terminology

A few key terms are introduced in this section for ease of reading. Further definitions can be found in section 19.3.

Trunk: A communications link designed to carry multiple signals simultaneously to provide network access between two points. It interconnects switching nodes.

Communication infrastructure: This is the backbone of the communication system over which telecommunication services are operated like data and voice services.

SCADA: Supervisory control and data acquisition, a computer system for gathering and analysing real-time data and used to remotely monitor and control equipment. Mostly used in telecommunication, utility, oil and gas industries.

Inter-control centre communications protocol (ICCP): Also known as IEC 60870–6/TASE.2, this is a set of international standards specified by utility organisations to provide data exchange over Wide Area Networks (WANs) between utility control centres, utilities, power pools, regional control centres, and non-utility generators.

Network slicing: This is a specific form of virtualisation that allows multiple logical networks to run on top of a shared physical network infrastructure. The different networks can then be built or designed to different specifications to meet different needs.

Ethernet: This is a set of standard technologies used for connecting networks together. These are used for carrying data and voice traffic.

Long-Term Evolution (LTE): This is a standard for wireless broadband communication for mobile devices. This is based on the GSM/EDGE and UMTS/HSPA technologies and is sometimes referred to as 4G LTE.

Transponder: An integrated wireless receiver and transmitter system used to transmit and/or receive radio signals.

Power Island: A part of the electricity network that is electrically disconnected from the larger grid and operated in an islanded mode, usually during a partial or total power system shutdown.

Distributed Restoration Zone (DRZ): Power Island in the distribution network used for Black Start purposes.

DRZ controller: A system that monitors and controls one or more DRZs.

IoT (Internet of things): Interconnection of computing, mechanical, digital and everyday objects via the Internet, enabling them to send and receive information.

Terrestrial trunked radio: (TETRA) is an open digital radio standard for professional mobile radio. TETRA can be used by a company for communication within private radio or commercial bases.

SDH (Synchronous digital hierarchy): is a standard technology for synchronous data transmission on optical media.

Very small aperture terminal (VSAT): This refers to any two-way satellite ground mounted or a stabilised maritime VSAT antenna with an antenna (dish) that is smaller than three meters.

Critical national infrastructure (CNI): Those critical elements of infrastructure, the loss or compromise of which could result in major detrimental impact on the availability, integrity or delivery of essential services; significant impact on national security, national defence, or the functioning of the state.

Latency: This refer to the delay that takes place during communication over a network.

Active network management (ANM) schemes: These schemes connect devices (generators, loads), actively and intelligently monitor and control the operation of the devices on the electricity network.

11.1.3 Background

During a traditional Black Start, NGESO leads the process, collaborating with TOs, DNOs and Black Start power station providers to restart the electricity grid after a total or partial shutdown.

The enacting of Black Start by NGESO currently requires an open voice communication channel between the applicable parties and in some cases visualisation of network or switching actions via SCADA/telemetry using the Integrated Energy Management Systems (IEMS).

Open communication as used here refers to having a dedicated and available trunk route for the named parties to communicate.

The voice communication requirements may vary depending on the phase of the restoration process. As discussed in section 7, the telecommunications interfaces are different under Black Start than normal operations. Furthermore, additional variations to this occur during the block loading phase (see figure 11.2).

Figure 11.1 depicts a traditional Black Start communications path with a Black Start (BS) power station as used in England and Wales. Open communication channels would be available during each phase of the restoration. For instance, the NGESO is expected to have two telephone trunk routes available.

The same principle applies to managing the Scottish LJRPs whereby the Scottish TOs can take the role of LJRP controller (instead of NGESO), forming their respective Power Islands. NGESO takes over the control of the Power Islands restored by the Scottish TOs, joining them to the electricity system.

Figure 11.1
Voice communications interface diagram under Black Start (Outside of block Loading)

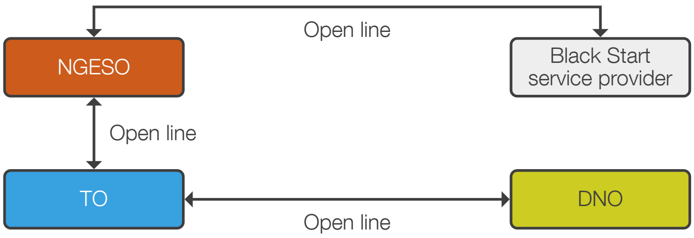
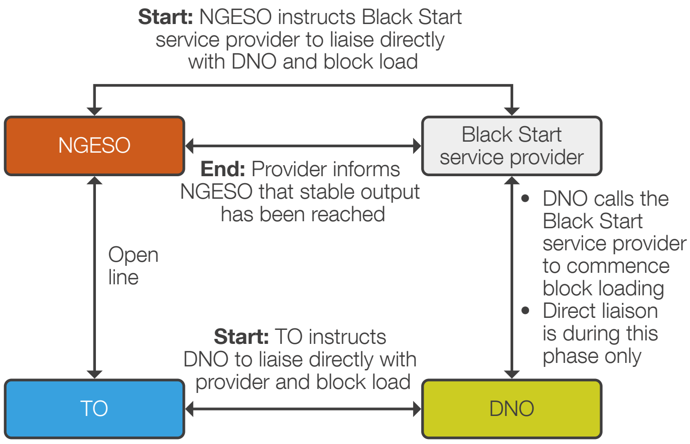


Figure 11.2
Voice communications interface diagram under Black Start (During the block loading phase)



11.1.4 Assessment of current telecommunication infrastructure

The telecommunication infrastructure is used for both voice and data communication, and this includes telephony, SCADA (telemetry), protection and data traffic for other operational applications such as the electricity balancing system, electricity planning tools etc.

In this section, we present a high-level review of the telecommunication networks currently utilised by Black Start participants for managing the traditional Black Start communication.

The National Grid Operational Telecommunication (OpTel) network is reviewed first because it is the designated network for traditional Black Start communication.

11.1.5 (OpTel) Network

The OpTel (Operational Telecommunication) network is a synchronous digital hierarchy (SDH) network owned by National Grid Electricity Transmission (NGET) and subscribed to by NGESO. It consists of a set of optical fibre and transmission equipment connecting National Grid's operational sites and leased circuits to third-party locations. The third-party locations include transmission connected power stations, some embedded generators, DNO control centres and other strategic sites. The OpTel network enables voice and data communication between the National Grid control centres and various sites. It carries control telephony, SCADA, protection and various other data traffic to support the operations of the transmission grid in England and Wales.

The OpTel network is currently Black Start power resilient as the communication path to support Black Start process is supported by a combination of battery and diesel back-up supply. The OpTel network is the designated network for traditional Black Start communication.

11.1.6 Telephony network:

The telephony network is used for both normal operational and Black Start voice communication between participants that manage the operation of the electricity grid. The telephone network utilises the OpTel infrastructure to route calls. It is currently a combination of switched and voice over IP networks.

11.1.7 National Grid ESO

The telephone network used in ENCC is called the 'control telephone', which is a dedicated telephone network used for operational purposes. This is a bespoke telephony application suite with features such as priority calling, short dialling and ability to receive more than one incoming call, amongst other functionalities. The control telephone is used to make and receive calls during both normal operations and Black Start. Importantly, the feature of the control telephones to allow simultaneous calls is utilised for Black Start open communication with NGET, Scottish TOs, DNOs and Black Start power stations, where applicable, in accordance with the specific Local Joint Restoration Plan (LJRP).

11.1.8 National Grid Electricity Transmission (NGET)

The NGET control engineers operate from the NGET Control. The NGET Control uses the same control telephone that is in use by the ENCC. This is because historically NGET and NGESO had been the same company prior to the legal separation of the businesses and still maintain the same telephony system. The features of priority calling, short dialling and the ability to receive more than one incoming call, amongst other functionalities, are also available. The telephone network also operates over the same National Grid dedicated private network (OpTel) as the NGESO.

11.1.9 Third-party sites

The Distribution Network Operator (DNO) control centres, Scottish Transmission Owners, power station sites and other strategic sites are classified as third-party sites in this report. The OpTel network extends to third-party sites via leased circuits or fibre cables for the provision of telephone, SCADA or other forms of communication. The telephones in use consist of the 'green' telephones used for operational calls with the National Grid control centres and the dedicated 'black' telephones used for Black Start.

In most cases, these telephones are extensions from the nearest NGET OpTel telephone exchanges to the site. However, there are occasions where the telephone extension is provided from third-party telephone exchanges, connected to the National Grid exchange using trunks.

The third party is responsible for providing back-up power supply to the active equipment in their premises. The equipment is usually housed in the control centres or substation equipment rooms that usually have back-up batteries, uninterrupted power supply units (UPS) and/or diesel backed generators.

11.1.10 Private Mobile Radio (PMR)

Some DNOs operate a PMR. This is a mobile system that serves an organisation in a closed user group, group call and push-to-talk. It has call set-up times that are usually shorter than the public mobile network. It utilises a base station around the required coverage areas. These base stations are usually mounted on substation sites and will take power supply from the substation grounds. The power resilience depends on the resilience of the sites and the mobile terminal which runs on rechargeable batteries.

From early designs, PMR systems have developed into 'trunked' systems. In these systems, a communication channel is allocated for the duration of a call and then automatically released to allow it to be used by another user. This technique enables multiple base stations to be connected and to provide coverage across a wider area than with a single base station.

11.1.11 Airwave
Airwave provides a mission-critical communication service used by Great Britain's emergency services and over 300 public safety organisations. Its network forms part of the Critical Network Infrastructure (CNI) and covers about 99 per cent of GB land mass. It is a trunked-terrestrial radio (TETRA) network, a two-way receiver specification, that is a global standard for digital trunked radio. It uses an advanced set of features, such as secure voice and data transmission, to manage the challenges of modern mobile radios. The network is designed to withstand major incidents and provide secure and speedy communications. Some DNOs rely on Airwave as back-up for their emergency communication needs and they consider this essential for their existing Black Start process.

The UK government is leading a programme to deliver a new emergency services network (ESN) critical communications system that will replace the current Airwave service used by the emergency services in Great Britain. This is discussed in section 12.3.2 and details can be found at: **https://www.motorolasolutions.com/en_xu/communications/esn.html**

11.1.12 Satellite telephones
Satellite telephones are utilised by some operators, such as the DNOs and TOs, to provide secure and reliable communication during emergency situations. Satellite telephones utilise radio through orbiting satellites instead of terrestrial cell sites as the mobile network. Either a clear view of the sky or an antenna (outside the building or vehicle) is needed to use satellite phones indoors. These can be utilised for Black Start communication, taking into consideration the power requirements of the handset charging points, the active equipment and earth station equipment, and weather. The active equipment can be housed in control centres backed by external power supplies that meet current power resilience requirements for the telecommunications equipment.

11.2 Applications used by NGESO and DNOs for managing Black Start

The data traffic used by the Black Start participants – NGESO, TOs, power stations and DNOs – for managing Black Start is carried over the OpTel network and utilised by various applications for operating and managing the GB transmission system in both normal and Black Start operations. The critical systems used for Black Start operations include:

- the integrated energy management system (IEMS);
- frequency and time equipment (FATE); and
- distribution management system (DMS).

11.2.1 NGESO and NGET applications

11.2.1.1 Integrated Energy Management System (IEMS)
The IEMS (sometimes called EMS – energy management system) is a suite of applications for controlling and managing the power system. It permits rapid re-switching and reconfiguration of the system by providing information to:

- enable management of the power system;
- operate switchgear; and
- switch protection circuits.

IEMS also provides a user interface from the substation control system (SCS), allowing the substation controls to be operated via telemetry.

The IEMS is configured to receive data from remote terminal units (RTUs) supporting GI74 and IEC 870–5-101 protocols. It has also been specified for ICCP links that connect to other third-party energy management systems.

IEMS communicates with the DNO equivalent energy management system (DMS) using SCADA analogue and digital data.

NGESO and NGET use the General Electrics (GE) XA/21 EnterNet suite of applications. Scottish Power Transmission use e-terra, also by GE.

11.2.1.2 Frequency And Time Equipment (FATE) System
The FATE System is an operationally critical system used by the NGESO to support second-by-second energy/demand balancing and NGESO's obligation to maintain the frequency within legal limits. The FATE display terminals in the control room provide a point of reference of the actual frequency which is a measure of the balance between generation and demand.

FATE also displays the real-time demand trace and the electric time error which is the difference between the electrical time and Greenwich Mean Time. The system is currently installed in substations covering 12 locations in England and Wales.

NB The greater the coverage or systems installed, the greater granularity and accuracy of the frequency measurements.

11.2.2 DNO applications

11.2.2.1 Distribution management system (DMS)
The DMS is the DNOs' equivalent of the IEMS. It is a suite of applications for controlling and managing the distribution power system, just as the IEMS is used for managing the transmission system and permits rapid re-switching and reconfiguration of the system by providing information to enable:

- power system management;
- operation of switchgear; and
- switching protection systems.

DMS also provides a user interface from the substation control system (SCS).

DMS communicates with National Grid's IEMS using SCADA analogue and digital data. The interface for connecting the DMS and IEMS is the Inter-control centre Communication Protocol (ICCP). This is used to exchange real-time data between the systems; indication and control can also be achieved using the ICCP.

Five of the six DNOs use the GE PowerOn Fusion energy management system, the remaining DNO uses the Schneider Electric distribution management system.

12. Telecommunications options analysis

Any telecommunication infrastructure would need to support the end-to-end voice and data communications necessary to facilitate the Black Start participants in restarting the power system safely and efficiently.

12.1 Introduction

In this section, we consider the infrastructure and technologies potentially available for Black Start from DER. Systems are considered in section 14. Any proposed telecommunication infrastructure would provide the required channel(s) for communication during a Black Start. As such, the design is required to support the end-to-end voice and data communications necessary to facilitate the Black Start participants in restarting the power system safely and efficiently.

The design will need:

- to be mains power independent i.e. meet any Black Start power resilience requirements.
- to meet defined security requirement considerations to withstand intrusion and attack.
- to provide a service that is always available with critical level service agreement and devoid of network congestion.
- to deliver a network path that is secure and provides open communication exclusively to Black Start participants during Black Start.

The following requirements are specific to voice communication:

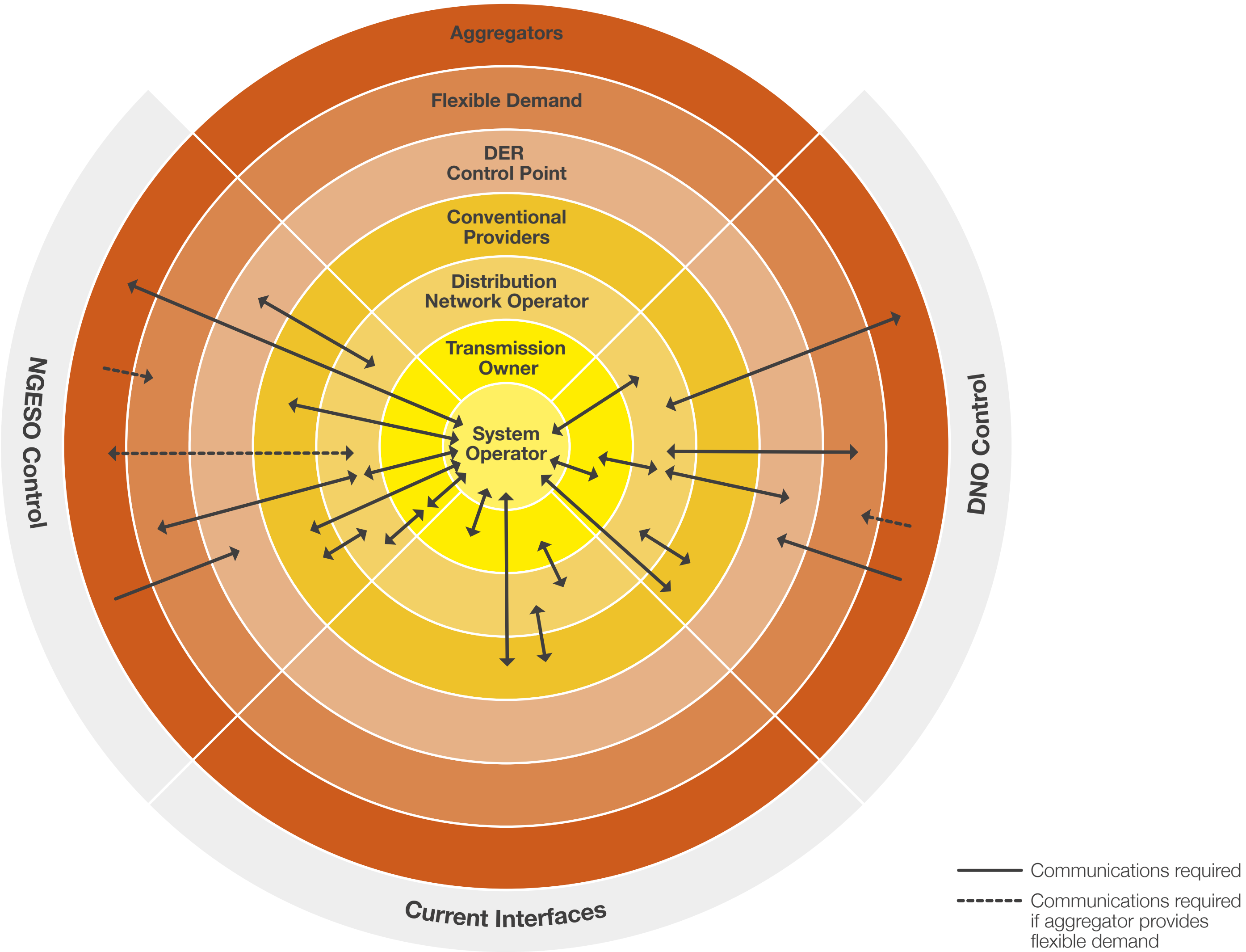
- The services provided must allow for a minimum of two simultaneous voice calls or any further communication requirement as determined by the LJRP.
- The telephone instrument ringing should be loud and distinguishable to alert operators.
- Calls between parties should be audible and clear. Calls should not be distorted by the network e.g. packet compression or jitter.
- Black Start calls should have priority over other calls.
- The telecommunications/telephone channels should have alternative connection routes for resilience.
- Duplication of active equipment to provide redundancy.
- The active connected devices should meet current power resilience requirements.
- The Black Start telephone should be easy to use with features to include short dial codes or programmable short dial facilities.

Data specific requirements are that the:

- network should support real or near real-time data traffic, such as SCADA traffic; and
- Black Start switching should have priority over other switching actions.

Distributed ReStart is exploring various options for delivering the telecommunications capability to enable Black Start from DER. We are considering both options for extending the current infrastructure to DER and to provide a total new network. Technologies being evaluated include those that are ready to be deployed immediately or on completion of the Distributed ReStart project by 2022.

Figure 12.1
Data and or voice exchange links required. Note that critical TO and DNO substations are assumed to have direct communications with the relevant party so are not separately identified



The communication currently used for traditional Black Start, the transmission-led restoration, has what is currently considered to be adequate power resilience. However, with the introduction of Distributed ReStart, it is yet to be determined whether this power resilience will be sufficient.

In addition to power resilience requirements, figure 12.1 demonstrates the additional complexity introduced in communication paths through the additional stakeholders involved in a restoration.

12.2 Telecommunication options available

Distributed ReStart has explored technological capabilities that are either currently available or are anticipated to be available in the next few years to deliver telecommunications facilities to DER sites. The options researched to deliver data and/or voice communication are considered below. We have focused on the most widely-known technologies. This is by no means an exhaustive list.

12.2.1 Satellite communication

A satellite communication is a two-way communication system utilising satellites positioned in orbit and satellite dishes designated as transmitters and receivers stationed on designated sites. The satellite uses a transponder to receive radio signals from one station/dish and retransmit it to the required earth location to establish two-way communication.

Satellites are positioned and operate in low, medium and geostationary orbits and these give indications of the satellite's altitude above earth.

Satellite communication technology has the potential to be a viable option to provide Black Start power resilient data and voice communication. It could be used to provide:

- simultaneous two-way open channel voice calls to designated Black Start participants;
- the data channel to support SCADA traffic and other signalling services that operate in real or near real-time.

Satellite communication is a wireless communication technology and, as such, the communication traffic is in open air, the inclusion of secure communication features to counter intrusion and disruptive attack and cyber defence is key to delivering this service. The satellite dishes require clear view to sky to transmit or receive signals as they will need to communicate with the satellite in orbit.

The channels would also need to be configured to have the required quality of services (QoS) to support voice over IP (VOIP) calls.

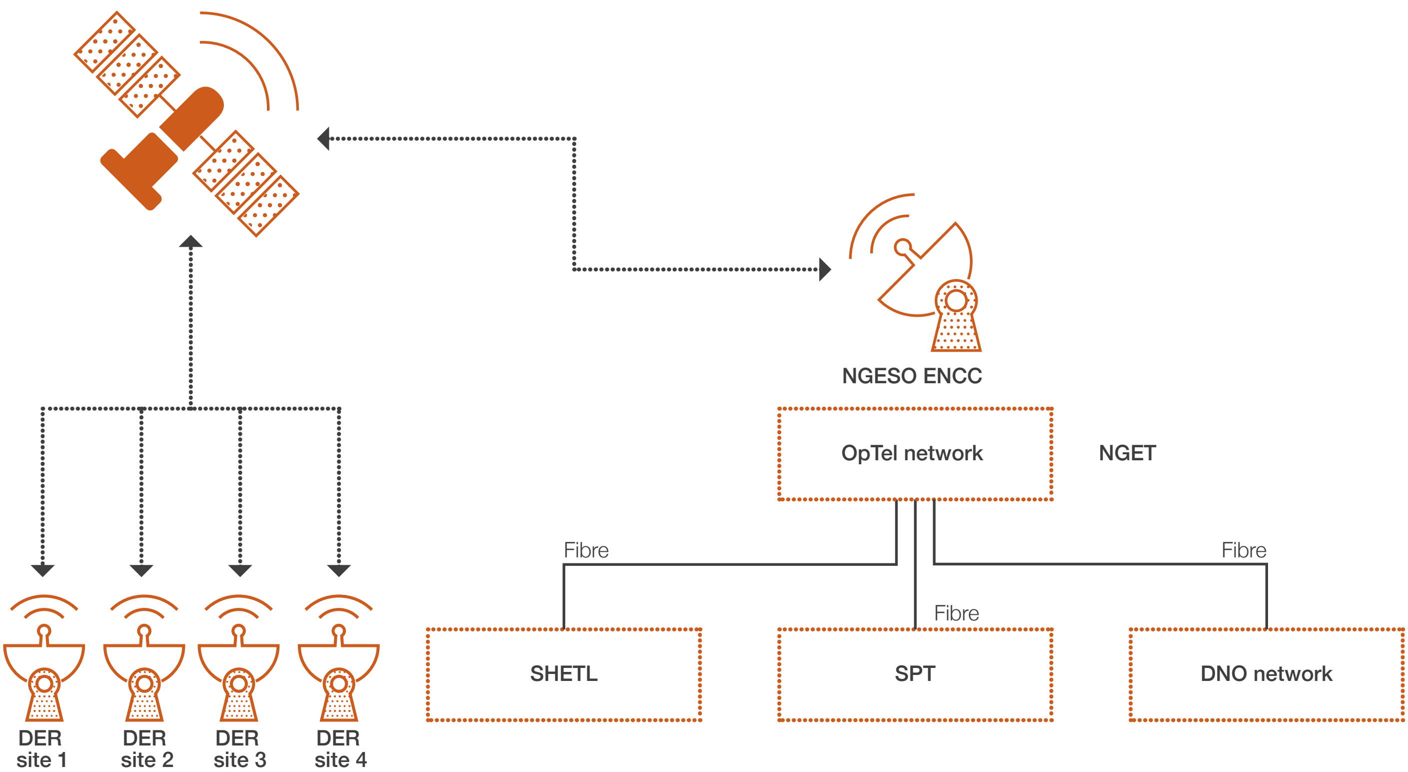
Satellite communication can be deployed in various forms, as described below.

12.2.2 NGESO main satellite hub interfacing with Very Small Aperture Terminal (VSAT) dishes at the individual DER sites

As shown in figure 12.2, NGESO hub satellite solution, using an NGESO main satellite hub that interfaces with Very Small Aperture Terminal (VSAT) dishes at the individual DER sites, would rely on the existing network between NGET and the DNOs. The additional service required to facilitate a Black Start service would be solely to extend Black Start power resilient communication to the DER sites.

NGESO OpTel network would serve as the connecting hub for traffic from DER sites to DNOs and other participants, where necessary, and vice versa.

Figure 12.2
NGESO hub satellite solution

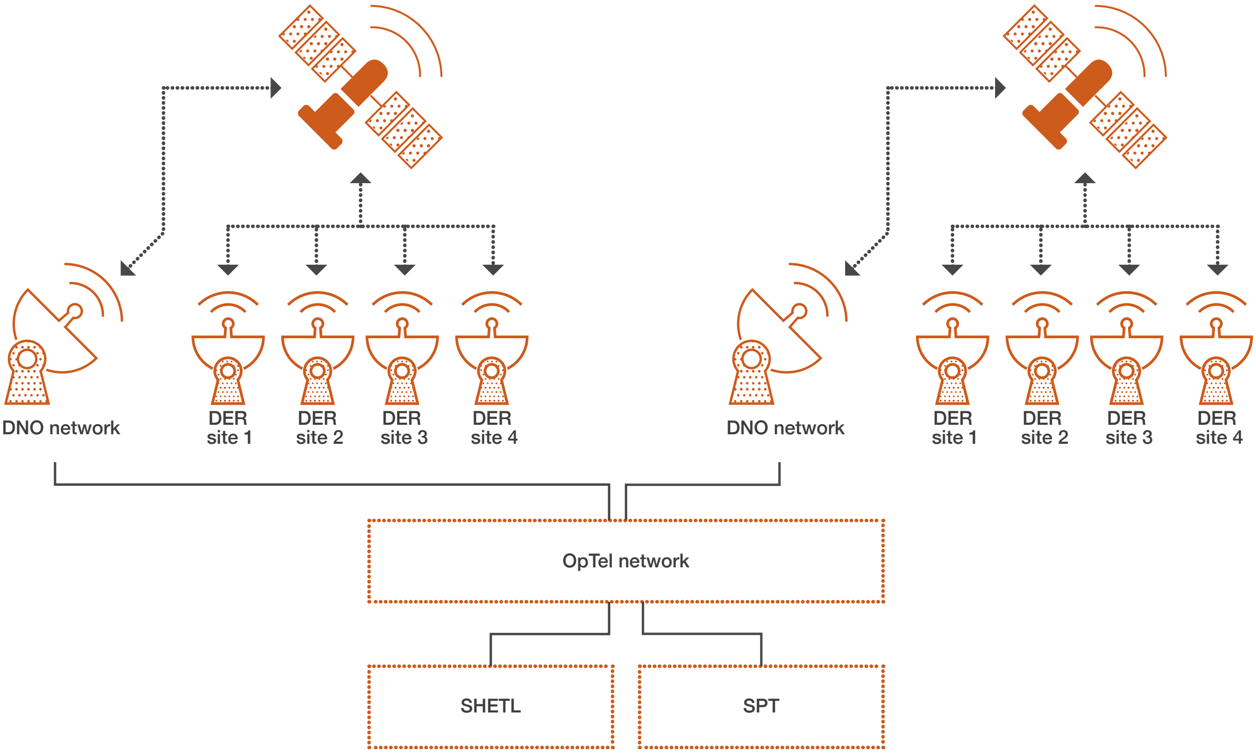


12.2.3 DNO hub Satellite solution

DNO hub satellite solution is alternative form of deploying satellite communication for Black Start. The satellite network would provide an extension of the existing Black Start network to DERs, as illustrated in figure 12.3 DNO hub Satellite solution.

This solution would require main satellite hubs at each DNO area and a network of corresponding VSAT dishes at the various DER sites. This may prove more expensive compared to the ESO main hub solution. However, this could be a fit where the DNOs already have a main satellite hub in place and it is only required to provide remote VSAT dishes to DER sites. The existing NGET OpTel network would connect the satellite network with the rest of the existing Black Start communication network.

Figure 12.3
DNO hub satellite solution



The use of satellite for voice communication could either be by using voice over IP (VOIP) on the data channel or direct use of satellite telephones. The use of satellite telephones for voice calls would require the use of external antenna but it would not require the installation of satellite main hubs or VSAT dishes and should not be seen as part of the satellite solutions described above.

The active devices used for the satellite hub station and VSAT hubs would require a back-up external powered source, capable of meeting Black Start power resilience requirements. The power requirement for the network could be met relatively easily, as active kits are only required at the two end nodes and could potentially be housed at the already power resilient control centres. The active end terminal equipment, such as satellite telephones, would also require external backed supply to extend the internal batteries power resilience.

12.2.4 Fibre optic cable deployment

Data and voice communication provision using fibre cable deployment could provide an option to deliver Black Start resilient communications. Fibre deployment could be either by single or multi-mode fibre cables. The fibre mode deployed depends largely on the distance between communication points and bandwidth requirements or transmission rates. Single mode fibres are used for distances of up to about 24–31 miles without active equipment, while multi-mode could go up to a mile and these distances varies with the transmission rate. Single mode fibre uses a more expensive equipment for deployment than equivalent multi-mode fibre and offers higher speed over longer distances.

The NGESO OpTel network currently used for the transmission-led Black Start communication is a fibre connected network. This network has been extended to provide communication to DNO control centres and required transmission connected generators.

Fibre networks are the most widely used technology for deploying voice and data communication where cable routes are practicable and feasible.

The active devices needed for fibre deployment include:

- an optical sending and receiving module;
- an amplifier; and
- an electrical adjustable attenuator.

Being 'active', these devices all require power resilient external power supplies.

Distributed ReStart has considered the various options to extend communications to DERs using fibre optic cables. Options include:

12.2.5 Fibre extension from OpTel to DER sites

Extending the OpTel network to DER sites using fibre effectively replicates how the NGESO/NGET OpTel network is extended to provide communication to DNOs or transmission connected generators. The resulting network would be used to provide SCADA and voice communication between the DERs and other Black Start participants using the existing infrastructure. The DER sites would be required to provide power resilient supply to the active equipment on their sites.

This method of extending the network would be practicable provided there is an accessible end-to-end cable route. The point of cable entry to OpTel network is usually a site that is accessible, has entry spare capacity, and possibly the shortest route to the intended DER site. This should also consider the requirement to provide dual fibre routes to a site with five metres separation requirement as currently stipulated for OpTel provision. This states that the fibres should be run five metres apart in a fibre duct for physical resilience. However, this is relaxed in some instances as determined by assessment and subsequent approval.

12.2.6 Fibre extension from DNO network to DER sites

Extending fibre cable from the DNO network to the DER sites is practicable where the DNO network is close to the DER site, and end-to-end cable route exist. There is potential for operational telemetry data from the DER to the DNO to be rerouted through this new network.

Where telemetry from the DER to DNOs currently exists, there may not necessarily be a Black Start power resilient power supply. The DER would need to provide independent power resilience to the active devices on their sites.

This arrangement would allow DNOs to connect DERs in their licensed areas only as the DERs would require to be telemetered to their respective DNO licensed areas.

12.2.7 Fibre solution incorporating satellite deployment

Fibre extension to DER sites from either the NGESO or DNOs could also be incorporated to either satellite deployment solution described earlier. A combination of solutions could be deployed:

- Satellite solutions or other wireless or open air communication technologies could be deployed where cable routes are not accessible.
- Fibre cables could be used where routes to DERs are easily accessible and are within technical feasible distance to deploy fibre.

For example, a communication path could include a combination of the following:

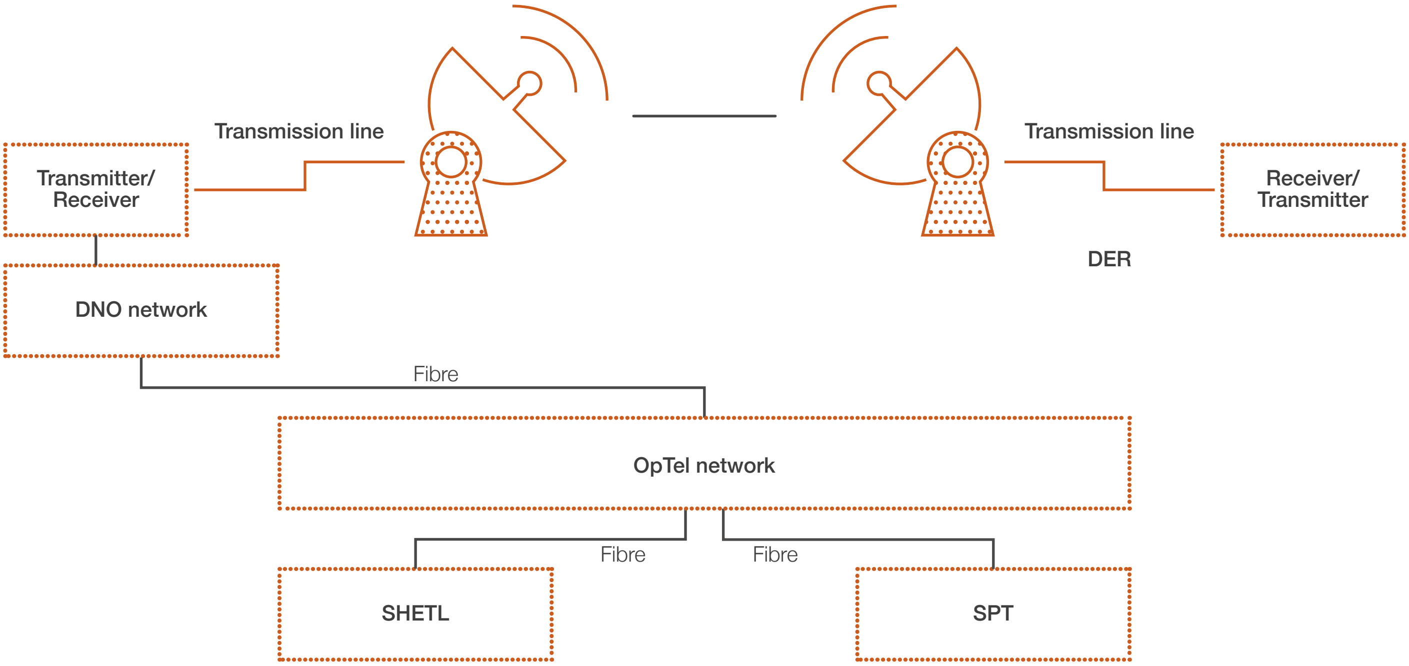
- An all fibre network from DER to DNO to NGET OpTel network.
- DER to DNO connection using satellite hub/open air communication and existing fibre routing from DNO network to NGET OpTel.
- Fibre cable connection from DER to a DNO for cable accessible sites, satellite hub/open air communication to connect DER to DNO network for non-cable accessible DER sites and the DNO to NGET OpTel connection through existing fibre cable.

12.2.8 Microwave radio

Microwave is a wireless technology. A microwave link from DER site to DNO could provide a remote site solution where a direct line of sight can be established between sites. Radio surveys can be used to determine suitability for microwave deployment. This solution could be used to extend DER communication to the DNOs, with the existing OpTel communication path connecting the DNOs to NGET OpTel network to provide end-to-end communication.

Microwave links are also open-air communication channels and, therefore, require the necessary data encryption and security to counter intrusion and security breach.

Figure 12.4
Microwave DNO – DER solution



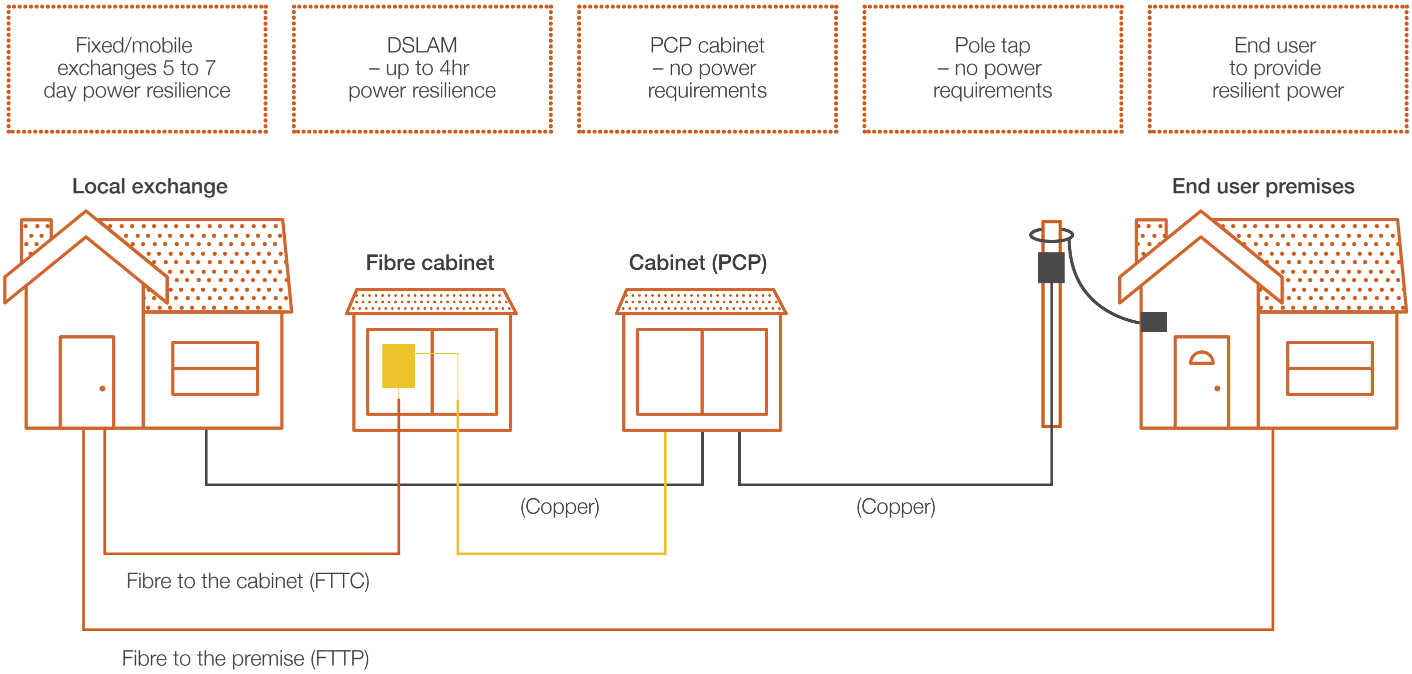
12.2.9 Private LTE

LTE is a wireless communications standard (fourth generation) that is designed to provide up to 10x the speeds of the 3G networks widely used for the current mobile network. The network could be tailored to be independent of traffic fluctuation of the wider area network and for more optimised performance, such as low latency and security. The service could also be configured to suit specialised network requirements usually associated with Operational Telecommunications and Black Start services. LTE could be operated by third-party providers or utilities themselves. LTE is associated with the 4th generation network and would require a licensed frequency spectrum to operate in the UK. Utility companies could jointly operate the LTE network that could be configured to meet the requirements for Operational Telecommunications and Black Start. This has the added advantage that the required resilience would be added to much fewer network nodes compared to the public mobile network and hence there could be a potential cost reduction. Network coverage along operational sites could be built in as there are cases where some operational sites do not have public mobile coverage.

12.2.10 BT Openreach products

There are various product offerings from BT Openreach that could potentially be used to provide remote access from the DERs to DNOs or NGESO. These offerings are fibre to the premises (FTTP) and fibre to the cabinet (FTTC) solutions as illustrated in figure 12.5: BT FTTP and FTTC schematics.

Figure 12.5
BT FTTP and FTTC schematics

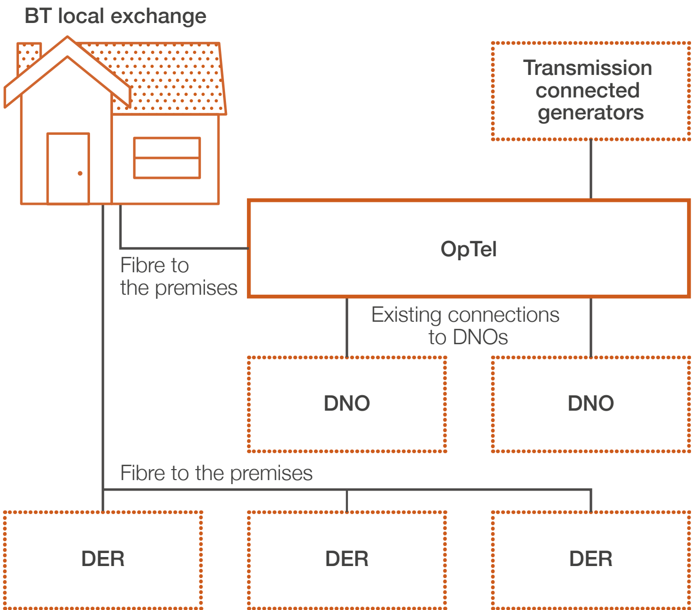


12.2.10.1 Fibre to the premises (FTTP)

This offering from BT Openreach is similar to the private network connected fibre solution described earlier. This option directly extends fibre from the nearest BT fixed or mobile local exchange to the customer premises. The local BT exchange houses the active equipment and, therefore, requires power resilience at this end. At the 'customer' end, the DER would be required to provide appropriate power resilience.

The BT Openreach network would connect DERs to either the DNO network or OpTel network for complete end to end communication. The DNOs or NGESO would also require a Black Start resilient connection to the BT Openreach network for complete end-to-end communication. This solution is dependent on BT Openreach's local exchange having the required power resilient requirement.

Figure 12.6
BT FTTP solution



12.2.10.2 Fibre To The Cabinet (FTTC)

This offering from BT Openreach extends fibre from the BT local exchange to fibre cabinets. This uses existing infrastructure that in most cases is shared by other users. Copper connections are currently used in the route from the fibre cabinet to the customer premises.

Fibre cabinets do not currently meet the Black Start power resilience requirements. Distributed ReStart is investigating whether, by special arrangement, BT Openreach could identify and increase the external power resilience of some specific fibre cabinets identified along the communication path to potential Black Start DER sites.

FTTC could be a viable option if there are a limited number of fibre cabinets along the path of communication.

12.2.11 Ethernet services
Ethernet Access Direct (EAD) and Ethernet Backhaul Direct (EBD) are ethernet offerings from BT Openreach that could be utilised to provide infrastructure to deliver data and voice services to DERs. These would need to be engineered to support the power resilient requirements.

12.2.12 Private radio and Airwave networks
The DNOs already use private radios as a means of communication within their organisation. This solution has proved to be a valuable resource at sites where public mobile service reception is weak and network availability is critical.

In most cases. the radio networks are integrated to the DNOs' internal operational networks. In areas where a radio service is currently available, there may be potential to incorporate DER sites for Black Start operation. For this to happen, the active devices (base stations and end terminals) would need Black Start resilient power supplies, and the radio network would need to be connected to the participants/DNOs' operational networks. This private radio network that is integrated to the DNO operational network would then use the existing interconnections to OpTel network to form an end-to-end Black Start communication network.

Private radios are also wireless communication technology and so encryption and cyber security considerations would be required.

12.3 Other options – Voice

Distributed ReStart has also considered the use of:

- the public switched telephone network (PSTN);
- Airwave mobile solution;
- emergency services network; and
- public mobile networks (4G/5G).

12.3.1 PSTN
As public switched telephone network (PSTN) uses copper to route the services, it does not require power at the customer end, allowing it to provide a viable communication channel where the local exchanges meet the required minimum Black Start power resilience. However, BT Openreach are in the process of withdrawing the PSTN as a service offering by 2025 and PSTN will not, therefore, be considered further by the project.

12.3.2 Airwave Solution and the emergency services network
Airwave Solution and the proposed emergency services network make use of a trunked-terrestrial radio (TETRA) network, with a two-way receiver specification. Today, Great Britain’s emergency services and over 300 public safety organisations communicate via the Airwave Network. Some existing Black Start participants also use Airwave solution and this solution could, theoretically, provide Black Start back-up solution for voice communication.

However, the government have announced its intention to replace the Airwave solution with the emergency services network (ESN) and this would limit the use of Airwave for future offerings. On the other hand, the emergency services network completion has been delayed and Distributed ReStart would not consider this further as an option as we do not have definitive timeline on when the services will be available.

12.3.3 Mobile networks (4G/5G)
The current mobile networks do not have mains power resilience to meet Black Start Standard. To meet Black Start power resilience requirements, we would need to install power resilient sources to active devices on existing mobile networks. There are numerous active devices that would require this back-up power, including numerous base stations and terminal devices. This option, therefore, has significant practical difficulties and we will not consider the existing public mobile network further in this analysis.

Public mobile networks of the future (e.g. 5G) could be viable options if external power resilience is considered by the network operators during the design and build phases.

Network slicing could be used to designate part of the network as a ‘Black Start’ network, tailored to fulfil the configuration related settings to meet Black Start resilience requirements.

12.4 Summary of advantages and disadvantages of the telecommunication options

At this stage in the project, current thinking is that that there will be no 'one size fits all' telecommunication solution. The solution deployed is likely to vary and will depend on the type and state of the current infrastructure of each participant, the terrain and future technology pathway. The following criteria will influence any chosen solution.

From our initial review and based on these criteria, we have set out some advantages and disadvantages of each technology in table 30.

12.4.1 Review criteria

Security

The security of the communication path is a key consideration. This may determine the availability of the service. Intrusion and disruption of the service via cyber attack is a major consideration. Generally, all communication links should have encryption in place. For the purpose of this paper, wired communication is presented as less prone to security attack because it will require physically breaching of the cable to gain access, while wireless could be breached from anywhere. However, this is open to challenge as wired communication could attract attention and the whole wired cable length may not be in secure or monitored areas. Another major consideration is availability of the service in adverse weather where a wired connection will fare favourably.

Ease of network deployment

The considerations in this area include access routes or wayleave agreements where wireless communication is considered favourably. The environmental impact of deploying a solution may also play a role such as digging up roads, impact on road users. Some technologies require clear sky access or line of sight between dishes and this may come into consideration. The number of active nodes may, in some instances, affect the technology chosen as these will require redundant power supplies for radio installations or mobile networks. The surveys done indicate that existing substations that have redundant power could house the base stations and, in this instance, could negate the above statement for privately owned wireless solution. For participants that already have an existing technology, it could be easier and cheaper to roll out the technology. In some instances, the skill set of the field staff and familiarity with a technology could influence the choice. Participants could want to install a radio network, where the field staff have the required skills to install and maintain the base stations, instead of satellites that require specialised skill sets.

Cost of deployment and ongoing operational cost

The cost of deploying a solution would in most cases affect which set of technologies that meet the technical criteria is selected. The technology and the deployment method could affect the cost. It is worth noting that the existing infrastructure could alter the cost. The start-up cost for a technology may be high, but if the participant already uses the technology, the incremental cost to extend the communication to the DER may be relatively cheaper overall. The ongoing operational cost could also influence the choice.

Future industry roadmap

The move to low carbon technology and DSO role may influence the choice of technology. Black Start communication should not be built in isolation but should be integral to the Operational Telecommunications network. The introduction to DSOs would require greater data exchange between the DERs and DNOs and the network of the future should have bandwidth with spare capacity to support such data exchange. This requirement would support the use of high bandwidth technology such as private LTE and others where applicable.

Table 12.1
Telecommunication options advantages and disadvantages table

Fixed networks	Advantages	Disadvantages
Fibre Optic Cable	The communication link is not affected by weather.	It requires physical access rights for cabling route.
	It has high availability as it is a physical structure with assured links.	There is a limitation to the length of direct fibre cable that could be used without adding active devices restricting its potential use.
	Any form of interfering with fibre communication will require physical access to the cables or equipment.	Fibre optic installation could take a long time due to the requirement for permissions, wayleave agreement and ground digging, limiting which parties could make use of cable.
	It provides high speed connection and low latency.	Ground installation can have a high environmental impact.
	It is relatively easy to provide power resilience as this is required only at the end points that house the active equipment (and repeaters can be used along route).	Incremental cost is always high.
Openreach ethernet services	These could be deployed in a relatively short time in areas where the services exist.	Availability and resilience would depend on providers of public infrastructure, it could be difficult to ensure their compliance.
	Could be a cheap option.	
BT Openreach FTTP	The communication link is not affected by weather.	Availability and resilience would depend on providers of public infrastructure, it could be difficult to ensure their compliance.
	It has high availability as it is a physical and assured link.	It requires access along route, right to the premises.
	Interference would require physically breaching the cable.	
	It provides high speed connection and low latency as with fibre products.	
	It is relatively easy to provide power resilience as this can be required only at the end points that house the active equipment.	
BT Openreach FTTC	These could be deployed in a relatively short time in areas where the services exist.	Availability and resilience would depend on providers of public infrastructure, it could be difficult to ensure their compliance. Typical resilience is low (1 min to 4 hours).
	It may prove to be cheap compared to other options.	The necessary power resilience is not currently in place. Provision may be challenging – it may require multiple active hubs and these will require independent power to meet Black Start Standard.
	The communication link is not affected by weather.	It requires access rights to the premises and wayleaves agreement.
	It has high availability as it is a physical and assured link.	
	Interference will require physically breaching the cable.	
Wireless networks	**Advantages**	**Disadvantages**
Satellite communication	Requires less active nodes, so can be easier to provide power resilience. • Resilience is required at the sending and receiving stations only. • The orbiting satellite has built-in power resilience from the sun and rechargeable batteries during its lifetime.	May be affected by adverse weather conditions; e.g. snow, heavy rain or storm may cause a temporary loss of satellite services as it can block either the signals being sent up to the satellite (uplink) or received (downlink).
	It covers a large geographical zone and it has no distance limitations.	It requires clear line of sight of the satellite. Local installation of an antenna is required for indoor operations.
	As a wireless technology, satellite technology does not require road access rights and cabling.	As with wireless technology, satellite signal could be intercepted if robust encryption and authentication is not deployed.
	For parties that already have a satellite network, the additional cost of extending the network to DERs could be relatively low.	Latency for packet transmission from source to destination is high due to distance of satellite from earth, which is about 36,000 kilometres, and so if not properly managed may impact real-time applications or communications.
	Deployment time can be relatively short, when compared to cabling options.	There can be limitations on the bandwidth.

Wireless networks	Advantages	Disadvantages
Microwave radio	It does not require physical access hence suitable for terrains where physical access rights are difficult.	It requires line of sight between the microwave dishes to operate.
	It provides high speed data and voice transmission.	As with wireless technology, microwave signal can be intercepted if robust encryption and authentication is not deployed.
	Installation timescales could be relatively short compared to wired communication.	May be affected by adverse weather conditions; e.g. snow, heavy rain or storm may cause a temporary loss of signal.
	It is relatively easy to implement power resilience as it is required at the end points only.	
Private wireless (LTE)	It does not require physical access hence suitable for terrains where physical access rights are difficult.	As with wireless technology, LTE signal could be intercepted if robust encryption and authentication is not deployed.
	It provides high speed data and voice transmission.	It will require a licensed spectrum to operate.
	Base stations could utilise existing substations that have the required power resilience.	Can be affected by adverse weather conditions; e.g. snow, heavy rain or storm can cause a temporary loss of signal.
Public mobile network (4G/5G)	The mobile network is already available or planned for and could be relatively low cost.	It may pose a challenge for real-time SCADA traffic and the required latency and bandwidth.
	It does not require physical access hence suitable for terrains where access rights are difficult or impractical.	Providing power resilience could be a huge challenge and outside of Black Start stakeholders' control.
		There are currently coverage issues around some operational sites. Most mobile base stations are concentrated around dense urban areas and substations are mostly located outside of these areas.
		Availability and resilience would depend on providers of public infrastructure, it could be difficult to ensure their compliance. Public mobile networks are not dedicated resources. They are designed for service consumers.
		As with wireless technology, the signal could be intercepted if robust end-to-end encryption and authentication is not used.
Private radio	For DNOs that already have private radio, extending the network to DERs could be relatively low cost.	As with wireless technology, the signal could be intercepted if robust end-to-end encryption and authentication is not deployed.
	The base stations could utilise existing substations that have the required power resilience.	There may be bandwidth limitations on what can be carried by the radio data modems due to bandwidth required for modern applications and volume of data required.
	It does not require physical access hence suitable for terrains where physical access rights are difficult.	

13. Systems option analysis

Systems are essential to the efficiency and ease of managing the restoration of power to the grid safely and efficiently.

13.1. Introduction

The systems required for managing DER in Black Start that have been identified as essential to the efficiency and ease of managing the restoration of power to the grid after a total or partial electricity system shutdown are considered below.

13.2. Essential systems

13.2.1. Energy Management System (EMS)

EMS is used to provide an up-to-the-minute view of:

- transmission or distribution network configuration;
- network equipment control;
- switching in or out of generation;
- load on the power system; and
- network status information.

This tool is essential to NGESO, the TOs and all DNOs for the day-to-day running of the electricity network and managing Black Start. Current EMS software is provided by General Electric (GE) and Schneider Electric.

The use of DER in Black Start may require additional connections and points on the EMS and hence the existing system would need to be able to accept:

- additional capacity: The system should have spare capacity to accommodate new database and SCADA points for DER and loads where required. It should also be able to accommodate new database and SCADA points.
- interoperability/interconnection: The DNO EMS should be able to interface with the NGESO EMS and vice versa. For the purposes of Distributed ReStart, the required details, i.e. 'what' and the 'level' of interaction that is required, will be determined by the 'Organisational Model' under consideration.

For ESO controlled models, the ESO needs a real-time view of the DNO energy management systems. The EMS should also have the ability to send commands/instructions between the ESO and DNO systems where required. The current method of connection between DNO and NGESO systems is the ICCP.

NGESO has implemented ICCP connections between the ESO EMS (XA21) and the DNO systems (PowerOn) (both GE products). As ICCP is an open standard protocol that is widely supported by the industry, it is believed the integration would work effectively with other products.

13.2.2. DRZ controller

The EMS should have the potential to interface with a DRZ controller, where the DRZ application could be an integral part of the EMS, or a separate entity working seamlessly with the EMS.

The EMS would be required to exchange configuration and data information with the DRZ controller, including real and reactive power flows, network configuration parameters, and switch status information. The DRZ controller should also be able to switch circuits or change configuration of network points on the EMS.

13.2.3. Generation and load balancing system

The entity tasked with controlling the restoration process would require the capability to balance the generation and load on the electricity transmission and distribution systems. This could be done either manually or using a 'balancing system'.

A balancing system would need visibility of both the generation and load/demand on the system under its instruction, and the ability to instruct the increase or decrease of generation or load in the system. This requires that the system or operator should have a reference or target frequency to work towards.

The current Black Start process is balanced manually, as it is only required on the skeletal transmission network, connecting a limited number of large generating plants. However, the introduction of a DER restoration process with potentially significantly more generators would make this an onerous task. In addition to the number of generators, the DER are much smaller in size and require large numbers of incremental balancing actions to meet the reference target frequency.

Note that the balancing system could form an integral part of the DRZ controller system.

13.2.4. Frequency management system

A frequency measuring system is essential to maintain a stable power system or Power Islands. The frequency measurement functionality could either be achieved by using a standalone system or it could be an integral part of a DRZ controller system, incorporating a phasor measurement unit (PMU) for frequency measurement.

Frequency measurement would be required for each autonomous area or Power Island.

13.3. DRZ controller

The DRZ controller could monitor and control the Power Islands set up for restoring the electricity system from the distribution network. A functional monitoring and control system (MCS) should fulfil the following considerations over other elements on the transmission or distribution network:

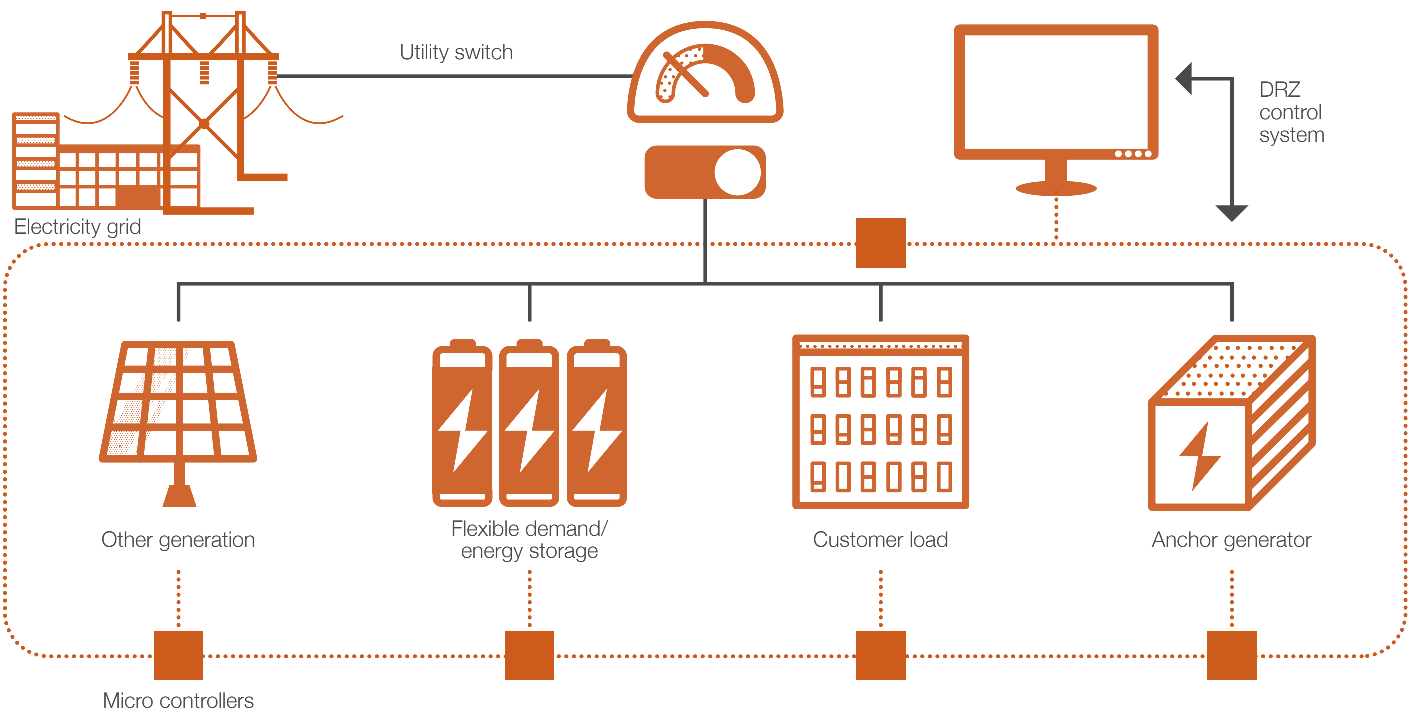
- Redundancy: an alternative communication route when the main route becomes unavailable.
- Availability: the bandwidth should always be available to send or receive signal information from the DRZ controller to the network components and vice versa.
- Priority: the DRZ signal/updates should have priority over other schemes on the network when in Black Start mode.
- Latency: the delay on the network should be within the operational limits for the application to function effectively.
- Secure over intrusion: the telecommunication network should be engineered to be secure against cyber attack or network intrusion.
- Seamless integration with existing systems: The system should interoperate with other relevant devices on the network e.g. ANM schemes.
- Power resilience: to the Black Start Standard, continuing to operate on mains power failure.
- Indication/alarm visibility: indication/alarms should show on the management display when automatic switching fails and the DRZ control should be able to revert to manual mode when required.
- Optimisation of available resources: the ability to optimise the use of generation and demand.
- Switching: the ability to switch circuits in automatic mode or send indication to another party to switch when the system is operating in manual mode.

The key micro gird controller functions are broken down into:

- network preparation and initialisation
- generation start up and control
- load pick-up
- Power Island stability
- Power Island expansion and interconnection
- transmission resynchronisation.

As illustrated in the following diagram:

Figure 13.1
Potential DRZ controller schematics



The main components include:

- Generation: A DRZ will require generation sources to provide energy supply to its connected loads. This would need to be embedded generation that could operate outside of the transmission network such as solar PV, wind, combined heat power (CHP), demand side response (DSR) or any other form of generation. An anchor generation would be required to provide frequency and timing regulation.
- Flexible demand/energy storage: An element of flexible demand or energy storage would be required to either provide a no-load energy for the generators or absorb energy that is produced when supply exceeds demand. This could be a battery bank or load bank.
- Load control: A load control is required to control end-users to optimise the generation and resources in the DRZ.
- Utility interconnection: An interface with the transmission system is required. This is for safe and reliable parallel operation of the DRZ and the power system. This should cater for the seamless disconnection and reconnection or re-sychronisation of the DRZ and the power grid.
- DRZ control system: A DRZ control system that interfaces with all the components together and maintains the real-time balance of generation and load. In a complex system, it consists of sophisticated software platforms, sensors, metering and communication devices designed for real-time optimisation and control of the generators, energy storage, loads, and utility interchange.
- The micro control system consists of island control units for connecting multiple islands, central supervisor, control interface and a measurement units. Measurements units could be obtained from a phasor measurement unit (PMU).

13.4 Further work

During the next phase of the project we will seek to better understand existing capability across the market to allow us to define minimum system requirements to facilitate process needs.

14. Cyber resilience

Cyber resilience refers to an organisation's ability to maintain the correct operation of its essential functions despite adverse cyber events. Its importance is growing as information systems are increasing in significance to businesses, and specifically, becoming critical to the operation of the energy industry.

At present, a limited number of Black Start participants utilise dedicated fibre links for Operational Telecommunications (voice and data), providing:

- robust, resilient Operational Telecommunications with low cyber security risk; and
- a GB-wide secure, reliable data and voice network for Black Start operation of the electricity grid (as well as for day-to-day operational management).

Introduction of DER into a Black Start process could lead to:

- a considerable increase in the volume of stakeholders;
- a reliance and therefore a need for Operational Telecommunications with new types of stakeholders, potentially aggregators and generator control points remote from the resources themselves;
- a vast increase in the number of data points;
- a rise in the number and types of potential Operational Telecommunications (e.g. microwave, satellite);

and so represents a potential increased risk in terms of ensuring cyber security and end-to-end power resilience.

Cyber resilience will require an end-to-end 'whole system' approach to ensure availability of Operational Telecommunications during a Black Start.

14.1. Approach

We have gathered information on the current and planned initiatives for cyber security by BEIS, Ofgem and the energy industry stakeholders. Any proposals we make in the next phases of Distributed ReStart will align and take account of any changes in legislation and guidance and Black Start participants' cyber policies. Our next steps will include analysis of these changes and policies to identify where Distributed ReStart needs to take account of cyber security issues over and above normal operation; and monitoring relevant projects and initiatives as they conclude.

Of particular note for this project and the energy industry is the E3CC (The Cyber Security Task Group), which is composed of information security leaders from energy industry stakeholders and reports to the Energy Emergencies Executive Committee (E3C). Its purpose being to:

- enable effective emergency planning and response;
- enable effective development of policy, standards and codes;
- enable increased resilience through risk identification and delivery of mitigation actions; and
- ensure continuous improvement through exercising and implementation of lessons learned.

An area of focus for the E3CC and the industry is the Network and Information Systems (NIS) Directive, the first EU-wide legislation on cyber security. It applies to those sectors that are vital for the economy and society, such as the energy industry.

14.2. NIS Directive

The UK has implemented the requirements of the NIS Directive through the Network and Information Systems Regulations 2018, which came into force on 10 May 2018. The NIS Directive provides legal measures to boost the overall level of network and information system security in the EU **https://www.gov.uk/government/collections/nis-directive-and-nis-regulations-2018**

Organisations that are identified by Member States as operators of essential services (OES) will take appropriate and proportionate security measures to manage risks to their network and information systems. OES will also be required to notify serious incidents to the relevant authority.

Under the UK NIS Regulations, the National Cyber Security Centre (NCSC) will be the UK's single point of contact (SPOC) and Computer Security Incident Response Team (CSIRT). The NCSC is also the UK technical authority on cyber security but enforcement will solely be the responsibility of the competent authorities.

In support of the NIS Regulations specifically, NCSC developed a set of 14 cyber security principles under four headings (Cyber Assessment Framework – CAF), a collection of supporting guidance and assessment tools. This is written in terms of outcomes – a specification of what needs to be achieved rather than a checklist of what needs to be done.

14.3. Further work

Our next steps will be to review the current cyber policies for Operators of Essential Services (OES); monitor possible impacts of new technologies and new initiatives, including those by BEIS, the ENA and technology providers; and agree the most appropriate way forward to help ensure end-to-end cyber security.

15. Telecommunications case study

In this section, we present an assessment of the potential impacts for delivering Distributed ReStart capabilities using two case studies taken from a sample of areas of the SP Distribution (SPD) and SP Manweb (SPM) networks that have a sufficient variety of DER, network topologies, network characteristics and restoration options to provide learning on a GB-wide basis.

15.1. Introduction

Analysis of the SPD and SPM networks has been undertaken to identify all areas that met the case study criteria defined for the project. The criteria covered a range of issues, but a key requirement was that each area should have a suitable generator to act as the "anchor" for a restoration process.

15.1.1. Case studies

In SPD, twenty areas of the network (predominantly 132/33kV GSPs), were identified as meeting the case study criteria. Six of these areas have been selected as proposed case studies.

The SPM network is considered in three geographic regions, Cheshire, Mersey and Wales.

- In Cheshire, there are six 132kV groups.
- In Mersey, there are three 132kV groups.
- In Wales, there are six 132kV groups.

Four SPM areas have been selected as case studies.

From the ten case studies, the two cases below are currently being considered to be taken forward and have been chosen for the purposes of assessing the ability of SPEN's existing and planned telecommunications infrastructure to support the implementation of Distributed ReStart from DER:

- Chapelcross grid supply point (GSP) in SPD in the Dumfries & Galloway District.
  - Chapelcross has been selected as the Stevens Croft biomass power station could act as the anchor generator and nearby wind farms might be added to expand the overall capability of the Power Island.
- Maentwrog supergrid in SPM in the Wales Region.
  - The Maentwrog 33kV network (in the Trawsfynydd 132kV group) has been selected as it provides the opportunity to study hydro generation as the anchor, interacting with wind and solar DERs in a rural network.

15.2. Assessment of relevant SPEN and NGET transmission telecommunications

The Operational Telecommunications Network in England & Wales interconnects to SPEN to enable:

- voice calls from the NGET control engineers who operate from the NGET Control to the SPEN control centre (SPENCC); and
- voice calls from the NGET control engineers who operate from the NGET Control to a subset of key SPEN Transmission and power station sites.

SPEN Management System is interconnected to NGET-IEMS via ICCP links for SCADA based SPEN network status updates.

In the future:
SPT-WAMS Systems may be deployed, as a result of the VISOR (Visualisation of real time system dynamics using enhanced monitoring) Project, and will be configured to send transmission based phasor and waveform data feeds to NGET.

SPEN may provide a data feed to NGET as part of an EU directive which would transfer renewable energy status information in near real-time, e.g. wind strength, maximum capacity, available capacity, and constrained capacity. The EU proposal is that the status information would be supplied by the DER supplier but transferred from the DER sites to NGET via the SPEN network.

The ENCC will need to establish voice calls to the SPEN as follows:

- to perform national Distributed ReStart coordination from the Electricity National control centre (ENCC) to the SPEN control centre (SPENCC); and
- if required, SPEN could permit NGESO Distributed ReStart calls to be transferred across the SPEN Telecommunications Infrastructure to the SPEN managed substations and DER sites.

15.3. Distributed energy resources

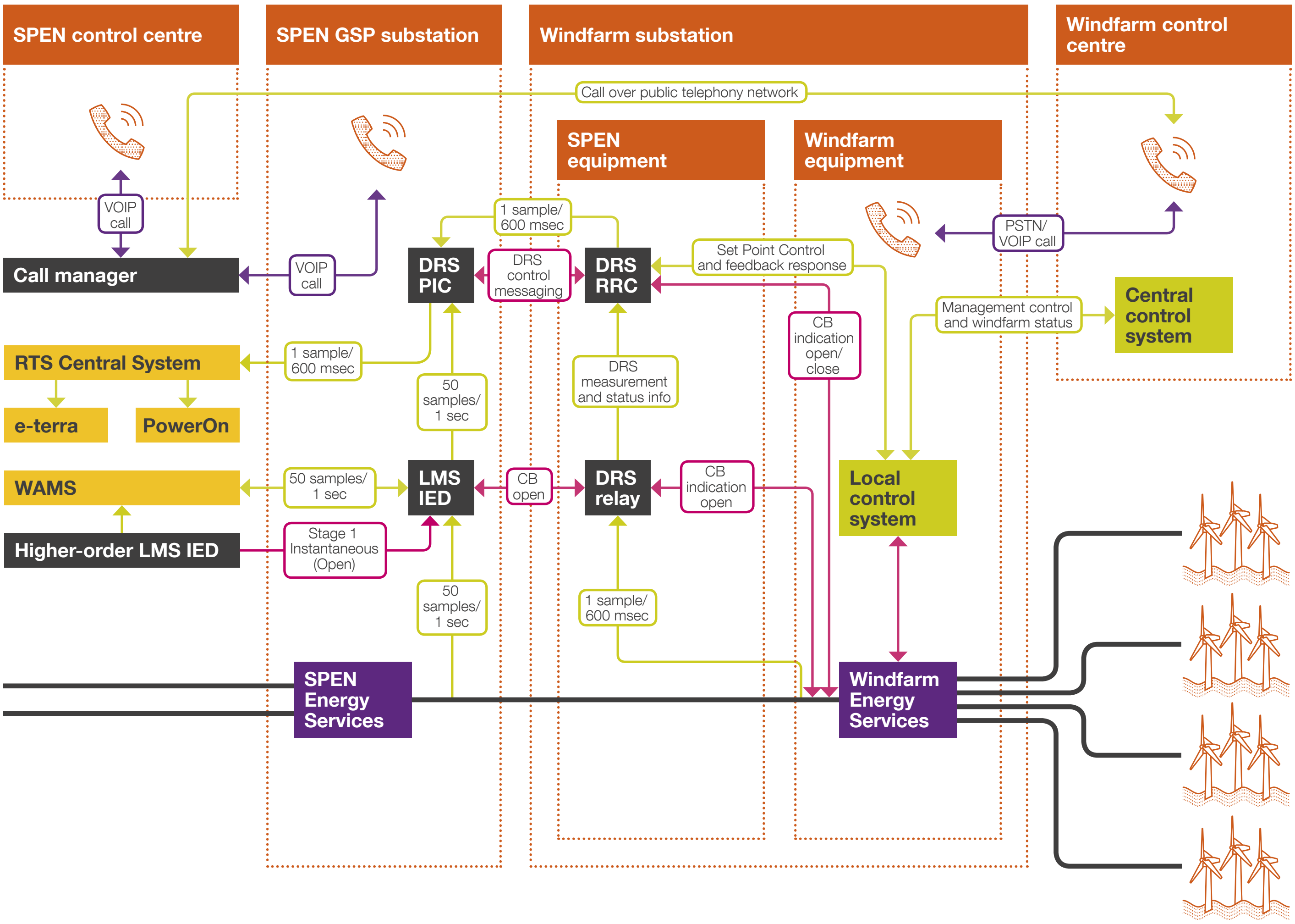
Many DER locations are operated remotely from centralised control centres, sometimes overseas. DER owners are unlikely to have Distributed ReStart communications resiliency from their centralised control centres to their remote DER sites. In a Distributed ReStart, it may be appropriate for SPENCC (and possibly NGESO) to communicate directly with the individual DER rather than go through a centralised control centre. Either way, there needs to be a mechanism to ensure communication to the DER site is maintained. Furthermore, some DERs may require on-site personnel during Distributed ReStart to perform tasks related to the start-up of generation and operation of the site.

Figure 15.1 highlights the following issues which may impact the ability to enable Distributed ReStart assets.

- Voice calls and data streams
  - DER assets could be remotely managed by the DER owners through a centralised control centre where the PSTN/VOIP calls and management control protocols are passed over public telephony networks which are not Distributed ReStart resilient
  - DER control centre personnel will need to speak with SPEN control centre personnel during Distributed ReStart but again any PSTN calls over the public telephony networks will not be Distributed ReStart resilient
  - SPEN control centre personnel will need to speak to on-site DER personnel at the DER site to coordinate the Distributed ReStart activities but again any PSTN calls over the public telephony networks will not be Distributed ReStart resilient
- Power resilience
  - Back-up power and generators at both the DER remote sites and the DER Central control centre Site may not support the minimum resilience required to bring up all the GSP Power Islands.

Figure 15.1 provides a possible example of a Distributed ReStart implementation, although it should be stressed that this example is given only to help visualise the issues associated with Distributed ReStart. The choice of solution will be dependent on a wide range of factors including the SPEN procurement process.

Figure 15.1
Possible example Distributed ReStart solution



15.4. SPEN telecommunications assessment

The assessment of the SPEN Operational Telecommunications Network identified the following issues of note.

SPEN Operational Telephone Network:

- An operational data network (ODN) has been deployed serving both SPD and SPM, which consists of fibre rings and provides diverse telecommunication paths between the centralised SPEN control centres, grid supply points, and supergrid sites.
- Protection against cyber attack is critical for UK critical national infrastructure and SPEN requires external third-parties to comply with the SPEN Code of Connection for interconnecting to SPEN's Operational Telecom Network at the designated external interconnection points, e.g. SP Kirkintilloch and SP Headquarters.
- Externally generated voice and data communications enter the SPEN Telecommunications Network through SP Kirkintilloch and SP Headquarters telecommunications interconnection points and not directly to the grid supply point (GSP) and substations due to cyber security concerns.
- It is assumed that NGESO will provide the required level of Distributed ReStart resilient telecommunications infrastructure from the National Grid control centres to the SPEN telecommunications interconnection points e.g. SP Kirkintilloch and SP Headquarters.
- The current transmission Inter-control centre communication protocol (ICCP) link for SCADA based SPEN network status updates to National Grid could possibly be extended to support status updates for DSO Distributed ReStart assets and specifically GSP and Power Island status.
- National Grid currently has voice connectivity to some of the key SPT transmission sites and to the SPM supergrid sites (132kV GSPs) and does not have connectivity to 33kV GSP sites in both SPD and SPM.
- The Operational Telecom Network in SPT is resilient against a single point of failure, will be Distributed ReStart capable from a power resiliency perspective, and the additional T2 investment will further strengthen that position.
- The SPEN SPD and SPM preferred approach is to connect DER sites via fibre but it could be more cost effective and practical to utilise wireless technologies as an alternative.
- SPEN currently utilise Airwave for SPEN operational personnel during Back Start and it is assumed that SPEN will migrate to the new UK ESN network in 2022 once it is fully operational and Distributed ReStart resilient across all SPEN licence areas.
- Power resiliency under ED1 price control requires SPEN to provide 72hrs' resiliency for all primary substations by 2020. Alongside this, we will continue to monitor and, where appropriate, work with stakeholders to confirm the actual requirement as soon as possible.

15.5. SPD – Chapelcross GSP assessment

SPEN has deployed an operational data network (ODN) serving Chapelcross, which is a Fibre Ring providing two diverse telecommunication paths between the centralised SPEN control centres and the Chapelcross 132kV GSP.

The DER sites identified to be utilised for Distributed ReStart have fibre connections which are either under construction or have been implemented already for the Chapelcross GSP ODN.

There are many SPD sites within the Chapelcross GSP area which may require additional battery back-up systems to be deployed to meet future power resiliency requirements.

The Craig Hill Wind Farm is not part of the proposed restoration strategy for Distributed ReStart for the Power Island but has been included for completeness. The communications link from Gretna to Langholm is quite challenging based on the location of Craig Hill Wind Farm to connect it into the ODN via fibre.

Chapelcross GSP has been identified as a GSP to be utilised for the implementation of the Dumfries & Galloway ANM Innovation Roll-out Mechanism project.

The design of a Power Island control system for Distributed ReStart will need to consider the other Services deployed within the Power Island and ensure that they are configured to support the restoration process or else disabled to prevent interference or unwanted control actions. This may include systems like ANM, Load Management Schemes, Inter-trip Protection Schemes, Network Controllable Points, and in the future Energy Trading Schemes.

GSP sites are not currently permitted to inter-communicate with each other directly and DER sites deployed across multiple GSPs are also not permitted to communicate to each other.

For Distributed ReStart, we would need to evaluate any increase in bandwidth, reductions in latency requirements and the required inter-communication between sites, especially for the procedure for joining up Power Islands if there is a need for inter-GSP communication.

15.6. Distributed ReStart alignment activities

The following activities are already underway or will be addressed outside of the Distributed ReStart project:

- SPEN activities:
  - Deliver all the fibre connections currently under construction in the Chapelcross GSP area by the end of 2019.

The following activities would be necessary based on the current design for Distributed ReStart at Chapelcross:

- SPEN activities:
  - Configure the ODN network to permit Distributed ReStart with DER elements to communicate with the GSP Power Island.
  - Increase the battery back-up capability for Distributed ReStart SPEN owned substation, electrical, and telecommunication assets to achieve future power resiliency requirements.

The following activities may be undertaken to enhance the Distributed ReStart from DER service and are subject to further analysis of the security implications, cost implications, and any commercial agreements:

- SPEN activities:
- If Craig Hill I and II Windfarms require some level of SCADA control during Distributed ReStart using DER then the battery back-up capability in Whita Hill Radio Hill Site and Langholm 33kV will need to be addressed but currently they have been identified as not requiring to be controlled during Distributed ReStart.
- Provide back-up communication links through the SPEN network via fixed or wireless telecommunication equipment to the following locations:
  - Chapelcross 132kV.
  - Distribution substations.
  - Stevens Croft Biomass.
- Call Manager System, Corporate Access Routers, and cyber security Firewalls would need to be configured to permit:
  - Possibly, VOIP calls from the NGESO ENCC to the Stevens Croft Biomass site, substations and Chapelcross GSP site over SPEN's network.
- DER activities:
- Stevens Croft Biomass to make changes as required to utilise the new communication links for Distributed ReStart activities for back-up voice communications. There are two possible solutions for utilising a SPEN communications link subject to cost and security implications:
  - DER supplier is provided with a dedicated VoIP phone for Distributed ReStart which is standalone and independent from the DER local area network.
  - DER supplier modifies the DER control centre dialling plans to route calls over the SPEN communications links if the DER primary communication link fails.

Please note: Stevens Croft Biomass site is managed locally and therefore there is no requirement for SPEN or NGESO to communicate to a centralised Command and control centre owned and operated by the DER supplier.

15.7. SPM – Maentwrog grid assessment

SPEN has deployed an operational data network (ODN) serving Maentwrog, which is a Fibre Ring providing two diverse telecommunication paths between the centralised SPEN control centres and the Maentwrog 132kV Grid.

SPEN predominantly utilise Ethernet Access Direct (EAD) links provided by British Telecom to interconnect SPEN sites within SPM as well as SPEN fibre links, which both provide point-to-point data connectivity within the Maentwrog Grid to the DER sites.

Bryn Bachau Solar Farm is the only DER site identified for Distributed ReStart that does not have any telecommunications connectivity in place.

SPM is interconnected utilising a mixture of BT EADs, BT KiloStreams, and BT MegaStreams which are deployed in two service configurations:

- Passive Power
  - The communication link relies on equipment deployed within SPEN facilities at the end of each link to provide operational power. The BT EAD is therefore not susceptible to power outages and SPEN UPS can be deployed at each end of the communications link to maintain communications during a power outage.
- Active Power
  - BT KiloStreams, BT MegaStreams, and BT EADs are deployed but the equipment is reliant on BT providing power to the BT equipment along the communication path in addition to any SPEN UPS provision at each end of the communication link. Therefore, these links are susceptible to power outages and are unlikely to meet the five days power resiliency for Distributed ReStart.

There are many SPM sites within the Maentwrog Grid area which may require additional battery back-up systems to be deployed to meet future power resiliency requirements.

Communication from the Maentwrog Grid to the SPEN control centres also utilise BT KiloStreams and MegaStreams along the communication paths which are also susceptible to power outages and are unlikely to meet future power resiliency requirements.

15.8. Distributed ReStart alignment activities

The following activities would be necessary, based on the current design for Distributed ReStart at Maentwrog:

- SPEN activities:
  - Configure the Operational Telecom Network to permit Distributed ReStart elements to communicate with the Maentwrog Grid Power Island.
  - Increase the battery back-up capability in the 33kV substations which are providing the intermediary telecommunication points of presence between the Maentwrog Grid and the DER sites to achieve future power resiliency requirements.
  - Identify individual communication paths between SPM sites which are provisioned utilising BT KiloStreams or BT MegaStreams and replace with alternative solutions such as dedicated SPEN fibre.

The following activities may be undertaken to enhance the Distributed ReStart from DER service and are subject to further analysis of the security implications, cost implications, and any commercial agreements.

- SPEN activities:
  - Provide back-up communication links through the SPEN network via fixed or wireless telecommunication equipment to the following locations:
  - Maentwrog 132kV
  - Distribution substations
  - Cwm Dyli and Maentwrog Hydros
  - Configure call manager system, corporate access routers and cyber security firewalls
  - Possible need for VOIP calls from the NGESO ENCC to the Maentwrog Hydro, Cwm Dyli Hydro, substations and Maentwrog Grid Site over SPEN's Network
- DER activities:
  - Maentwrog Hydro to make changes as required to utilise the new communication links for Distributed ReStart activities for back-up voice communications. There are two possible solutions for utilising a SPEN communications link subject to cost and security implications:
  - DER supplier is provided with a dedicated VoIP phone for Distributed ReStart which is standalone and independent from the DER local area network.
  - DER supplier modifies the DER control centre dialling plans to route calls over the SPEN communications links if the DER primary communication link fails.
  - Cwm Dyli Hydro to make changes as required to utilise the new communication links for Distributed ReStart activities for back-up voice communications.

There are two possible solutions for utilising a SPEN communications link subject to cost and security implications:

- DER supplier is provided with a dedicated VoIP phone for Distributed ReStart which is standalone and independent from the DER local area network.
- DER supplier modifies the DER control centre dialling plans to route calls over the SPEN communications links if the DER primary communication link fails.

Please note: Cwm Dyli and Maentwrog Hydros are assumed to be managed locally and therefore there is no requirement for SPEN or NGESO to communicate to a centralised command and control centre owned and operated by the DER supplier.

16. Conclusions

16.1. Summary of conclusions

Our analysis to date has allowed us to establish:

- typical capabilities of current Black Start participants;
- a high-level generic process to deliver Distributed ReStart;
- which models to take forward for further analysis; and
- the broad requirements and options for future Operational Telecommunications.

Through these findings, we have concluded that there are no OST blockers to delivering Distributed ReStart. However, in addition to the standard approach to development of processes and procedures (i.e. one of simplicity and clarity) there are some important requirements to include in the design phase:

- Familiarity: Black Start responsibilities, interfaces and systems should align closely with BAU operations.
- Resilience: End to end Operational Telecommunications resilience is required (including power resilience and resistance to cyber or physical attack).
- Flexibility: There is unlikely to be a 'one size fits all' solution.

17. Next steps

The next phase in the OST workstream is the design phase (from November 2019 till September 2020), when our depth of understanding will increase to allow development of draft proposals.

The foundation for this work will be the next steps as summarised within this section.

In the next phase of the work, cost and viability analysis will be applied to a range of case studies across our models. Working closely with the Power Engineering and Trials (PET) and Procurement and Compliance (P&C) workstreams we will thus define process and specification, ultimately delivering a coherent design.

There will be a need for some flexibility in approach, particularly as other external initiatives and projects conclude.

Table 17.1
Next steps for the Organisational Systems and Telecommunications Workstream to Deliverable 2 (October 2020).

Lead work area	Approximate completion	Description	Details
Workstream	Q3 2020	Compare models with Operational Telecommunications	Objectives are to compare the organisational models with the Operational Telecommunication options to establish which options work together.
Workstream	Ongoing	Further engagement with all stakeholders	Principal objectives are to understand minimum automation requirements and refine the models for further review.
Workstream	Q2 2020	Align with evolving DSO/DNO developments	Ensure alignment with wider projects and industry changes, specifically the ENA Open Networks projects.
Workstream	Q2 2020	Applicability across GB	Identify means of interfacing between technologies currently used across ESO, DNOs & DERs.
Workstream	Q4 2020	Report writing	Drafting all information into a report structure for deliverable 2.
Organisational	Q3 2020	Develop desk-top exercises for each organisational model.	To include development of each element of a Distributed ReStart process. • Using a desk-top exercise-based approach, we will refine process responsibilities and commence development of a basic model for future training. Active stakeholder validation will be sought.
Organisational	Q3 2020	Draft organisational requirements	To include an assessment of current structures against people required to deliver the organisational models; assess the skill requirements and the training required to bridge the gaps; and identify where further automation, systems or tools are a minimum requirement for control or restoration within appropriate timeframes. Validation is expected to take place through workshops.
Organisational	Q3 2020	Process Map	Assign appropriate responsibilities for processes to each party involved in the DRZ process.
Telecommunications	Q3 2020	Develop draft telecommunications requirements/ specification	To include appropriate levels of: Bandwidth Security Availability Latency Physical resilience Power resilience
Telecommunications	Q3 2020	Telecommunications options	Analysis to identify the circumstances under which each telecommunications option becomes economically viable. Expect to include case study/consultant engagement.

Lead work area	Approximate completion	Description	Details
Systems	Q3 2020	Cost benefit analysis	To establish to what extent is it more economic to use an automated system or process compared with additional staff. To include the cost of restoration timeframe per the published Black Start Standard (dependency).
Systems	Q3 2020	Define existing capability and possible manufacturers through stakeholder engagement	Understand existing capability across the market and define minimum system requirements to facilitate process needs. Dependency on PET workstream.
Cyber	Q2 2020	Cyber policies	Review the current cyber policies for Operators of Essential Services (OES).
Cyber	Q3 2020	Development of cyber principles	Following the review of current cyber policies, and noting possible impact of new technologies and new initiatives by stakeholders including the government, we will seek to create potential functional specifications for cyber principles for Distributed ReStart participants.

Assurance accuracy statement

This progress report has been produced in agreement with the entire project hierarchy. The report has been reviewed by all project partners. The report has been approved by the Distributed ReStart, Organisational Systems & Telecommunications work stream lead and by Peter Chandler the Project Lead. Every effort has been made to ensure all information in the report is true and accurate.

Peter Chandler

Peter Chandler
Distributed ReStart – Project Lead

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19. Appendices

19.1. Distributed ReStart project questionnaires for Distributed Network Operators

National Grid Electricity System Operator (NGESO) is currently undertaking a NIC funded project that will demonstrate Black Start from Distributed Energy Resources (DER). This will be restoration from the distributed level against the current transmission-led restoration. This is by coordinating the number of DERs to provide a safe and effective Black Start service.

This will increase competition in the market, and deliver cost and carbon emission reductions.

These set of questions will help the project team assess the DNOs' current organisational and telecommunication capabilities, identify gaps and propose potential options to deliver Black Start restoration from DERs.

Roles/Responsibilities	Comments
How is your organisation structured in terms of roles and responsibilities for business as usual (BAU) liaison with Distributed Energy Resources (DER) connected to your network? Do your engineers engage directly with DER engineers or go through aggregators/company call centre?	
Who (in terms of role) is involved in the current Black Start process with National Grid? (control room and day staff) Switching engineers? Planning team?	
What are the key responsibilities of the roles engaged in current Black Start with National Grid Electricity System Operator?	
How many people are currently required in your control room to manage Black Start? And how many are trained to manage Black Start?	
Do you have (how many) staff skilled in the following: – Generation despatch – Voltage and frequency control – Demand forecasting – DER reserve and response arrangements	
Processes	**Comments**
Do you have a process for Black Start or are you in a process of making a plan? What is the current process (how are engineers called up to attend site? Are you called up from your control centre or/and standby engineers called from home?	
Are there any planned changes to these processes if they exist?	
Are there any challenges/options to improve? Please state any suggestion you may have and how it may improve the process.	
How might current processes need to change to accommodate an active role in Black Start?	
How enthusiastic are DNOs in taking up responsibility of restoration/Black Start in their licensed area? Any foreseen challenges?	

Data systems	Comments
Do you have visibility of all DERs on your network? i.e. are they telemetered to your energy management system (DMS)? If not, are there rules/policies that determine what is telemetered? i.e. 10MW and above is metered to DMS?	
Can you send command/instructions to connected DER on your DMS?	
Can you switch DER resources on your DMS? Do you have the capability to switch DER resources automatically/via telemetry?	
Do you switch the DER or send instruction for the DER engineers to switch themselves?	
Do you attend site to initiate control/energisation or is this automated via telemetry? Or both? When do you have to attend site? Are there policies dictating when to attend site?	
What computer systems/applications do you rely on for Black Start? DMS? Planning tools? Real-time operation tools?	

Telecommunication	Comments
How do you speak with DERs? Do you call them on your/their mobile? Desk telephone? And do you call on a public network e.g. BT number?	
Do you have special features on the telephone to them? Priority calling? Assured route? Special ringing/louder than usual alerting?	
Do you have alternate means of communicating if the primary route fails? Airwave? Satellite?	

Infrastructure	Comments
Do you have a private/internal telecommunications infrastructure?	
What technology does your network constitute of? Fibre, SDH network, VSAT, microwave? Ethernet? Satellite?	
If you operate a private telecommunications infrastructure, how long will your network last on mains failure? i.e. what is the power resilience and battery/generated back supply last? Does the resilience vary? Please state.	
Do you rely on BT/public network/leased lines for connection across multiple sites? Do you have information on the power resilience for those connections?	
Does your private network extend to DER sites for communication? To all DERs connected to your network? Or some and what is criteria for having it in some and not in others?	

19.2. Organisational systems and telephony RAID register

ID	Risk description and impact	Deliverable impacted	Mitigation actions and contingency	Status
1	The eventual organisational & systems design restricts capability to a limited number of DNO areas. This could reduce project benefits.	Org, Systems & Telecommu-nications	Expected modifications to case study networks to facilitate testing of Black Start from DERs have been included in the project budget. During the development phase, we will assess the technical suitability of the case study networks. A key criterion for progression to online testing will be the cost of network modifications required.	Risk
2	Numbers of control engineers required due to complexity in Power Islands is not practical for existing relevant system operators.	Org, Systems & Telecommu-nications	This is an options risk, relevant to any options considered during the lifespan of the project.	Risk
3	Roles & skill sets required for DER are challenging to resource.	Org, Systems & Telecommu-nications	Optioneering will determine the skill sets and will need to be managed carefully.	Risk
4	High cost of providing sufficient resilience in telecommunications means focusing on a small number of large resources, limiting involvement of smaller DERs.	Org, Systems & Telecommu-nications	Identified as a high dependency, will need careful managing during optioneering.	Dependency
5	High dependency on external work, projects & technical developments.	Org, Systems & Telecommu-nications	Black Start Standard – requirement on telecommunications resilience is dependent on how long the telecommunications network can operate without power. Optioneering dependency.	Dependency
6	Cyber security.	All	Key aspect of resilience across the full project – it is not mentioned specifically in the BID, this may incur additional cost and effort – Scope creep.	Risk
7	Organisational, technical, procurement and regulatory proposals do not align. This could reduce project benefits.	All	Design Architects are included in the project team to align outcomes across various workstream lead weekly meetings – job function will support the mitigation against this risk. This is based on learning from previous innovation projects. NIC Governance Guidelines.	Risk
8	Partner companies may not maintain/provide resource at planned levels. This could result in project delays.	All	All partner companies have a nominated Project Management function to ensure internal resourcing remains at the required levels to meet deliverables	Risk

19.3. Key terms and definitions

Key term	Definition
Active Network Management (ANM)	Active Network Management (ANM) connects separate components of an electricity network such as smaller energy generators, renewable generation, storage devices, etc by implementing software to monitor and control the operation of these devices.
Air Wave	A mobile communications company which is utilised by Great Britain's emergency services using a private mobile radio technology.
Anchor Generator	A generator with the ability to establish an independent voltage source (grid forming capability).
Black Start	The procedure necessary for a recovery from a Total Shutdown or Partial Shutdown.
Bulk Supply Point (BSP)	A point of supply from a transmission system to a: Distribution System.
Communication Infrastructure	This is the backbone of the communication system over which telecommunication services are operated like data and voice services.
Critical National Infrastructure (CNI)	Those critical elements of infrastructure, the loss or compromise of which could result in major detrimental impact on the availability, integrity or delivery of essential services; Significant impact on national security, national defence, or the functioning of the State.
Distributed Energy Resource (DER)	DERs are electricity-producing resources or controllable loads that are connected to a local distribution system or connected to a host facility within the local distribution system.
Distributed Restoration Zone (DZ)	Power Island in the distribution network used for Black Start purposes.
Distributed Restoration Zone (DRZ) Controller	A system that monitors and controls one or more DRZs.
Distribution Network Operator (DNO)	A company licenced to distribute electricity in the UK.
Distribution System Operator (DSO)	A future entity responsible for actively operating the distribution network. the ENA are currently investigating various DSO 'worlds' outlining the division of responsibility and which entity is most appropriate to fulfil this activity.
Electricity System Operator (ESO)	National Grid Electricity System Operator Limited (NO: 11014226) whose registered office is at 1–3 Strand, London, WC2N 5EH as the person whose Transmission Licence section C of such Transmission Licence has been given effect.

Key term	Definition
Emergency Instruction	An instruction issued by The Company in emergency circumstances, pursuant to BC2.9, to the Control Point of a User. In the case of such instructions applicable to a BM Unit, it may require an action or response which is outside the Dynamic Parameters, QPN or Other Relevant Data, and may include an instruction to trip a Genset.
Ethernet	This is a set of standard technologies used for connecting networks together. These are used for carrying data and voice traffic.
Gold Command	Gold Command is the strategic response team which is concerned with corporate communications issues and governmental liaison.
Grid Supply Point	A grid supply point where either: (i) (a) the Network Operator or Non Embedded Customer had placed Purchase Contracts for all of its Plant and Apparatus at that Grid Supply Point on or after 7 September 2018, and (b) All of the Network Operator's or Non Embedded Customer's Plant and Apparatus at that Grid Supply Point was first connected to the Transmission System on or after 18 August 2019; or (ii) the Network Operator's or Non Embedded Customer's Plant and Apparatus at a Grid Supply Point is the subject of a Substantial Modification which is effective on or after 18 August 2019.
House Load	Operation which ensures that a power station can continue to supply its in-house load in the event of system faults resulting in Power Generating Modules being disconnected from the system and tripped onto their auxiliary supplies.
Human Machine Interface	A software application that presents information to an operator about the stage of a process.
Inter Control Centre Communications Protocol (ICCP)	Also known as IEC 60870–6/TASE.2, is a set of international standards specified by utility organisations to provide data exchange over Wide Area Networks (WANs) between utility control centres, utilities, power pools, regional control centres, and Non-Utility Generators.
Internet Of Things	Interconnection via the Internet of computing, mechanical, digital and everyday objects, enabling them to send and receive information.
Load Management System (LMS)	Load management systems also known as demand side response systems adjust/control electrical load rather than generation output to balance supply of electricity.
Local Joint Restoration Plan (LJRP)	A plan produced under OC9.4.7.12 detailing the agreed method and procedure by which a Genset at a Black Start Station (possibly with other Gensets at that Black Start Station) will energise part of the Total System and meet complementary blocks of local demand so as to form a Power Island. In Scotland, the plan may also: cover more than one Black Start Station; include Gensets other than those at a Black Start Station and cover the creation of one or more Power Islands.
Long-Term Evolution (LTE)	Long-Term Evolution (LTE) is a standard for wireless broadband communication for mobile devices. This is based on the GSM/EDGE and UMTS/HSPA technologies and sometimes referred to as 4G LTE.
Main Interconnected Transmission System (MITS)	All 400kV and 275kV supergrid elements of the onshore Great Britain transmission systems, and in Scotland the onshore 132kV elements of the transmission system operated in parallel with the supergrid.
Network Segregation	The process of isolating electricity networks to provide discrete power demand in 'blocks'.
Network Slicing	This is a specific form of virtualisation that allows multiple logical networks to run on top of a shared physical network infrastructure. The different networks can then be built or designed to different specifications to meet different needs.
NIS Directive	EU wide legislation on cyber security.
OpTel	National Grid Electricity Transmission operated power resilient fibre optic network.
Power Island	A part of the electricity network that is electrically disconnected from the larger grid and operated in an islanded mode, usually during a partial or total power system shutdown.
PSTN – Public Switched Telephony Network	Circuit switched telephone network, providing infrastructure and services for public communication.
Remote Terminal Unit	An electronic device that interfaces between physical assets and a control system.
Supervisory Control And Data Acquisition (SCADA)	A computer system for gathering and analysing real-time data and used to remotely monitor and control equipment. Mostly used in telecommunication, utility, oil and gas industries.
Silver Command	The tactical response team which liaises between the operational command and control function, non-operational external parties and the Gold Command function.
Synchronous Digital Hierarchy	A standard technology for synchronous data transmission on optical media.
Technology Readiness Level (TRL)	A method for estimating the maturity and suitability of technologies.
Terrestrial Trunked Radio (TETRA)	An open digital radio standard for professional mobile radio. TETRA can be used by a company for communication within a private radio or commercial bases.
Transmission Network Owner (TO)	A company licenced to transmit electricity in the UK.
Transponder	An integrated wireless receiver and transmitter system used to transmit and/or receive radio signals.
Trunk	A communications link designed to carry multiple signals simultaneously to provide network access between two points. It interconnects switching nodes.
Very Small Aperture Terminal	This refers to any two-way satellite ground mounted or a stabilised maritime VSAT antenna with an antenna (dish) that is smaller than 3 meters.