NIA Project Close Down Report Document

Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

Network Licensees must publish the required Project Progress information on the Smarter Networks Portal by 31st July 2014 and each year thereafter. The Network Licensee(s) must publish Project Progress information for each NIA Project that has developed new learning in the preceding relevant year.

Date of Submission

Nov 2023

Project Reference Number

NIA2_NGESO047

Project Progress

Project Title

Distributed ReStart – Redhouse Live Trial

Project Reference Number

NIA2_NGESO047

Funding Licensee(s)

NG ESO - National Grid ESO

Project Start Date

February 2023

Project Duration

0 years and 11 months

Nominated Project Contact(s)

Michael Kenny, Julie Balch

Scope

Several types of DERs were considered in the Distributed ReStart NIC project, to demonstrate that the solution is applicable across technology types and across all of GB. The project focussed on DERs that have reached at least a TRL 4 in the context of providing Restoration services (thermal power stations, small hydro stations, wind farms and small gas or diesel stations) whilst remaining open to considering other technologies. The case studies identified have a mixture of synchronous and non-synchronous generation types, from both dispatchable and intermittent resources, this will provide an opportunity to explore technology options.

This project is designed to deliver tested and proven concepts and frameworks that can be directly implemented into BAU, assuming the concept is technically and economically viable. It will enable a restoration from any DER technology once certain TRL levels are attained.

This follow-on NIA project will support an additional live trial at Redhouse GSP will demonstrate the use of a battery energy storage system (BESS) with grid-forming technology to restart the network and use of a prototype Distribution Restoration Zone Controller (DRZC) to stabilise and maintain the power island within voltage and frequency limits.

Objectives

Following the completion of the second live trial at Chapelcross in July 2022, the project has successfully met all 10 of its original and agreed objectives. These were agreed with Ofgem at the start of the project, and were designated as deliverables in the Project Direction:

Organisation, Systems & Telecoms (OST):

- Defined the communications requirements for this process including automation via a new DRZC (Deliverable 1).
- Confirmed the new organisational design, roles, and responsibilities (Deliverable 2).
- Demonstrated how the restoration process and joint action would work in practice between the Electricity System Operator (ESO), Transmission Owners (TOs), Distribution Network Operators (DNOs), and Distributed Energy Resources (DERs) via desk-top exercises (Deliverable 3).

Power Engineering & Trials (PET):

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

Procurement & Compliance (P&C):

- Defined the approach and process to procure services from DER providers (Deliverable 7).
- This was demonstrated via our procurement test event (Deliverable 8)
- Facilitated distribution restoration through ongoing industry code changes (Deliverable 9).

Ofgem Deliverable 10 is designated as the Project Closedown report, which is in the process of final development ahead of the formal closedown of the project in October 2023.

In addition, the project has progressed further than the original project plan with the inclusion of the build and test of a Distribution Restoration Zone Controller (DRZC) prototype that allows for automation (with control room engineer direction) of the creation and stabilisation of a local power island.

We have also requested a further extension to the project to 31 October 2023 (with a proportionate addition to our funding via this NIA request) to deliver a third live trial at the RedhouseGSP. This will involve use of a battery energy storage system (BESS) with grid-forming technology to restart the network and use of the prototype DRZC to stabilise and maintain the power island within voltage and frequency limits. The project plan now includes two new trial aims, split across three distinct phases over a two-week test period from 29th May – 9th June 2023:

Phase 1
Deliver Phase 1 proving grid forming capability of Distributed Battery Energy Storage System (On 3rd party network only).

Phase 2
Deliver Phase 2 proving grid forming capability of BESS and ability energise both 33kV and 132kV transformers / network.

Additional Goals (Phase 3):

- Include Middle Balbeggie Solar farm within tests to demonstrate ability of multiple DER to contribute to islanded grid.
- Implement DRZC control of island to demonstrate ability to simply respond to disturbances or have complete control of island.

Success Criteria

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

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

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

All required Ofgem deliverables have now been met and the project has delivered enhanced value and learning through the innovative development of the DRZC concept and the additional live trial at Redhouse planned for June 2023. In terms of success criteria, this will be measured across two Phases as detailed in Section 2.4 above.

Phase 1 – successful manual restoration of the Redhouse GSP by:

- Proving grid forming capability of Distributed Battery Energy Storage System (On 3rd party network only).
- Proving grid forming capability of BESS and ability energise both 33kV and 132kV transformers / network.

Phase 2 – successful automated restoration of the Redhouse GSP by:

- Implement DRZC control of stable power island to demonstrate ability to simply respond to disturbances or have complete control of island.
- Include Middle Balbeggie Solar farm within tests to demonstrate ability of multiple DER to contribute to islanded grid.

Performance Compared to the Original Project Aims, Objectives and Success Criteria

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

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

Project Overview

The Distributed Restart NIC project explored how Distributed Energy Resources (DERs) can be used to restore power in the event of a total or partial shutdown of the GB Electricity Network. Current approaches rely on large power stations and interconnectors but, as the UK moves to cleaner and more decentralised energy, new options must be developed, leading to reductions in both cost and carbon emissions.

Two live trails have been completed at Galloway and Chapelcross Grid Supply Points (GPSs). This follow-on NIA project supported an additional live trial at Redhouse GSP to demonstrate the use of a BESS with grid-forming technology to restart the network and use of a prototype DRZC to stabilise and maintain the power island within voltage and frequency limits.

Throughout this document, references to 'The Project' refer to the past activities and Ofgem mandated deliverables of the Distributed Restart NIC-funded Innovation project. References to the Redhouse Live Trial, refer to the additional live trail of a Battery and Solar Farm at the Redhouse Grid Supply Point (GSP), which has demonstrated the ability of non-synchronous generation at the Distribution level to restart the network, and energise the local SPEN transmission network, utilising the automation made possible by the Distributed Restart Project's Distribution Restoration Zone Controller (DRZC). This live trial was delivered via NIA and has extended the original project's deliverables to as close to a BAU implementation as possible.

Project Plan

Based on the latest project cost/benefit analysis, the developed method has the potential to deliver financial benefits of at least £115m (net present value in 2018/19 prices) and carbon benefits of 0.81MT of cumulative avoided CO_2e for consumers by 2050, breaking even by 2027 (within 5 years of the end of the project).

Extending the project to deliver the Redhouse live trial within this NIA project has brought additional benefits to the consumer, using economies of scale and existing expertise via the project as opposed to time and financial costs in starting a new 'Redhouse' project from scratch. It has also brought benefits to industry by 'de-risking' the rollout of the new Electricity System Restoration Standard (ESRS), demonstrating that automation is achievable in an operational/BAU environment.

The Redhouse live trial took place on Monday, 19th June 2023 and concluded two weeks after, on the 30th of June.

The final steps for this NIA project, consisted of delivery (by our project partners SP Energy Networks) of the Redhouse live trial, as detailed in the Objectives & Success Criteria sections previously discussed in this NIA report. Following that successful trial, the project has publicised the 3rd and final Power Engineering & Trials workstream report on our website and communicated out to our Stakeholder database – this was supported by a Webinar on Wednesday, 11th October 2023, as this coincided with the formal project closure activities, closure of the project bank and the return of any unspent funds to the appropriate funding bodies (NIA).

Project Activities

For this second and final project progress report for NIA2_NGESO047, a lot of additional progress has been made inside the Distributed Restart project:

1. The required legal agreements required for participation in the live trial were negotiated and completed at the end of May 2023, in time for the Redhouse live trial to begin.
2. This allowed the final installation activities to be completed on the trial participants networks, in order to fully protect both the participants and the consumers relying on uninterrupted supplies of electricity from the relevant sub-stations in the Redhouse GSP.

The monitoring and control of a distribution restoration zone (DRZ) is complex, as it involves co-ordinated control of several resources with different technical characteristics within a zone to maintain power balance and stable frequency as load is restored. The system must also accommodate varying loads and renewable generation, and ride through unplanned disturbances while the network is in an unusual and fragile state. The testing and validation of the monitoring and control system is an important element of successful deployment of DRZs.

The Distributed ReStart project has explored methods of testing various aspects of the system. The learning obtained from the project is important for defining the process to qualify monitoring and control to co-ordinate the operation of a zone. Testing is required to confirm each part of the system, as well as the functioning of the whole scheme.
The learning from the Distributed ReStart NIC project was fed into the Redhouse Live Trial and also helped to create the testing practices that are appropriate for further business-as-usual (BAU) roll out of the approach. In general, the testing process for BAU should be:

- Systematic to prove the whole system performance.
- Streamlined for an efficient, repeatable, and standardised process.
- Aligned with project flow for zone deployment without holding up implementation.

In addition to the DRZC Automation testing report, the Distributed ReStart NIC project has also published a consolidated 'Frequently Asked Questions' document, which gathered together all questions and answers across the 4 years of the project. The questions came from across industry and were captured via a variety of methods, including events, webinars, presentations, podcasts, and face-face meetings, and represent a unique and lasting reference source for organisations embarking on their roll-out of individual programmes and projects.

Required Modifications to the Planned Approach During the Course of the Project

Changes to scope and approach

There have been no material changes to the original project aims, objectives and success criteria.

Changes to cost

Project costs identified in the PEA submission have remained unchanged, and we maintained our robust approach to management of project finances as we progress towards completion of our remaining closedown activities in support of the completed and successful Redhouse live trial.

Changes to programme

There are no additional changes to the project, and our existing approach delivered a successful live trial, follow-on workstream final report and provided proven confirmation to industry that use of asynchronous renewable generation, coupled with innovative automation will deliver 'business as usual planned benefits to consumers, starting in 2025.

Lessons Learnt for Future Projects

The Distributed ReStart project has led to the development of clear and detailed information to allow other network operators and industry stakeholders to understand how distributed energy resources (DERs) can be used to restore power in the highly unlikely event of a total or partial shutdown of the national electricity transmission system (NETS).

To provide a central, focused point for accessing this information, the outcomes of the project are presented in our 'Final Findings and Proposals for Electricity System Restoration from DERs' report, allowing interested parties involved in the BAU rollout of contracting for distributed generation, to be able to understand how Distributed ReStart can be applied on their networks, and where detailed supporting information can be found.

Review of benefits case

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

The original 2018 CBA calculated a net present value (NPV) of up to £115m by 2050. A small update to this CBA, based on interim project learning, was then provided in the 2020 end of year report. This resulted in an increased NPV of £145m. In our formal Closedown report for the original 10 Ofgem deliverables, we provided a further update to the CBA which, compared to the original 2018 version, incorporates further project learning, updated data and assumptions, and some refinements of the overall modelling methodology. The updates described above have resulted in an updated calculated net present value of £130m.

Note: The following sections are only required for those projects which have been completed since 1st April 2013, or since the previous Project Progress information was reported.

The Outcomes of the Project

Final project outcomes

Since the award of NIA funding in February 2023, the final live trial has been delivered at Redhouse, including preparation of the necessary legal agreements for the Redhouse trial to go ahead with the trial generators. These were successfully completed, but remain confidential, and as such will not be publicly available on the website. Interested parties with a legitimate need to view these agreements may refer to the statement at the end of this document if required. In addition, we have produced the third and final Power Engineering & Trials (PET) Part 3 report on our website, along with hosting a Redhouse Live Trial webinar on Wednesday 11th October 2023. Almost 100 external project stakeholders attended, to meet the presenters virtually, and ask detailed questions from the engineering experts on the bridge.

Background

This report details the methodology, results and findings from the Distributed Restart Redhouse live trial, undertaken in June 2023. This trial was the third and final trial undertaken as part of a series of world-first trials. The trials were designed to provide detailed understanding on how distributed energy resources (DERs) can build, maintain, and optimise power islands isolated from the main grid – with a view to driving down the time it would take to restore the network following the extremely unlikely event of total shutdown of Great Britain's electricity grid.

The traditional top-down approach would be complimented by the DER enabled bottom-up approach to help ensure the target of 60% of demand would be restored within a 24-hour period from 2026 onwards, as detailed in the Electricity System Restoration Standard (ESRS).

The trial at Redhouse was fundamentally different to the two previously completed trials at Galloway and Chapelcross in that the anchor generator for this test was a non-synchronous inverter-based asset, this being a BESS, as opposed to a synchronous generator. Details of how the test network was enabled, what tests were undertaken, and the result of the tests are included in this report, alongside supplementary supporting material.

The tests took place at SP Energy Networks' Redhouse substation near Glenrothes in central Scotland. The test networks' main elements comprised of:

- 11.6 MVA (8 MW, 8 MWh) grid-forming capable BESS.
- 24 MVA 11/33 kV primary distribution transformer connected via an underground cable.
- 10 MVA 11/33 kV primary distribution transformer connected via an overhead line (OHL).
- 5 MVA load bank used to simulate customer demand.
- 3 MVA solar farm utilised as the top-up generator for the island.
- 90 MVA 33/132 kV grid transmission transformer located at Redhouse.
- 10.6 km 132 kV OHL to the neighbouring Glenniston substation.
- 33 kV earthing transformer (ET) for use during the tests when another earth point was not connected.
- Supporting 5 MVA diesel genset and auxiliary supplies.

Summary of findings

The tests overall were hugely successful, and the BESS' performance was tested and observed to be excellent when acting as the anchor generator for the power island. Furthermore, the tests proved that:

1. BESS can be utilised as anchor generators to start, maintain, and control power islands very effectively, with the aid of diesel gensets or without.
2. They can energise both distribution and transmission transformers and lines and are much more effective at doing so when point on wave (PoW) switching is active.
3. The block load pickup (BLPU) capability of the BESS when compared to synchronous generators of the same capacity is far superior and, in this case, needed to be derived as opposed to measured due to its ability to outperform the biggest load step the equipment could implement (4 MW).
4. The DRZC can automate the startup and operation of the BESS system, optimise the power island's performance, and can utilise its functionality to resync with the intact grid.
5. The island assets can be used together as a dynamic virtual power plant (DVPP) and dispatch load or generation as needed when connected to the grid.
6. Comparatively small diesel gensets in isolation can energise both distribution and transmission transformers and lines and are much more effective at doing so when point on wave (PoW) switching is active.

Ultimately, these world-first tests set a precedent for the use of BESS assets to be used, not just in the UK but around the world, as viable network restoration service providers.

Data Access

Details on how network or consumption data arising in the course of NIA funded projects can be requested by interested parties, and the terms on which such data will be made available by National Grid can be found in our publicly available "Data sharing policy related to NIC/NIA projects" and www.nationalgrideso.com/future-energy/innovation.

National Grid Electricity System Operator already publishes much of the data arising from our NIC/NIA/SIF projects on the National Grid ESO Data Portal (data.nationalgrideso.com) and the Smarter Networks Portal (www.smarternetworks.org). You may wish to check these websites before making an application under this policy, in case the data which you are seeking has already been published.

Foreground IPR

All the workstreams have delivered reports that fully satisfy the Project Direction from Ofgem. These have been published on the Key documents webpage of the Distributed ReStart website: Distributed ReStart | National Grid ESO. The final PET Report (Part 3) will also be published on the project website at the end of October 2023.

More detail on the relevant foreground IPR can be found in section 5.3, page 34 of the original NIC Submission Document.

For a comprehensive list of all our foreground IP developed by the project, please refer to the Documents Library section of the Distributed ReStart project website.

Planned Implementation

In October 2022, whilst this project was still running, the ESO started engagements with generators and DNOs in support of new tenders for restoration services, which now include scope for distribution connected resources drawing directly on learning gained from the Distributed ReStart project. The ESO has a section on their website, Restoration Services, dedicated to these activities.

Actions Required by Network Licensees

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

The sessions included the organisational change impact assessment and training needs analysis developed as recommendations from the Distributed ReStart project workstreams.

Actions Required by Non-Network Licensee Parties

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

DRZC Functional Design Specifications

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

SEL Engineering Services: Distributed Restart Zone Controller FEED

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

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

The call to action to the DERs engaged with, also applies to SEL, ZIV, GE Digital and SGS (and other, potential technology suppliers) to continue considering how to engage with DNOs and DERs in discussions on how their specific DRZC specifications could be rolled out into DNOs active network management (ANM) and/or distributed energy resources management systems (DERMS) solutions.

Technical Network Modifications

In addition to the above changes that would be required, extensive technical details of network modifications that DNOs and DERs will need to make to implement a successful distributed restoration service on their assets have also been published.

Section 2.0 of the Final Findings and Proposals report gives a detailed overview of the key technical findings and recommendations that have been derived from the successful live trials at Galloway and Chapelcross, as well as extensive information from the various network studies. The key findings have been more fully summarised below:

In the transition to BAU, it will be necessary for all DRZ participants to tackle the technical challenges identified in the project analysis and live trials. This is being driven by the ongoing process of ESO tendering for new restoration services and working with the DNOs and DERs to assess viability and define workable DRZs. DER owners will need to determine what service(s) they are able to provide, in terms of:

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

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

- **33 kV network earthing** – Existing earthing schemes must be evaluated to identify changes required to ensure safe operation, especially during initial start-up of the anchor generator and resynchronisation of the power island with the wider system.
- **Network protection** – Existing protection functions and settings within the proposed DRZ must be reviewed to ensure safe operation throughout the restoration process, which may require the use of different settings during the early stages when fault levels are at their lowest. Many modern protection relays have group settings functionality that allows different settings to be used but the details of how this would be implemented in each DRZ would need to be assessed.
- **Switchgear capability** – Studies should be performed to assess risks of transient recovery voltage (TRV) for fault and normal switching operations (together with the associated phenomena of reignitions for vacuum interrupter circuit breakers); the capacitive breaking capacity of switchgear should also be considered. To overcome the technical and human resource constraints associated with establishing and maintaining a DRZ, the DNO may have to implement automation in the form of a DRZ Controller.

This will primarily be required if either of the following "top-up services" are required:

- **Fast MW control** – This enables the block load pickup (BLPU) capability of the anchor DER to be enhanced (its ability to pick up instantaneous blocks of demand) to make a viable restoration strategy (e.g. pick up primary [33/11 kV] substations in a single step). The DRZC is truly innovative in requiring sub-second control of DER to achieve this (to maintain acceptable frequency levels). This DRZC function is called fast balancing.
- **Energy MWhs** are required to enhance the capacity of the anchor DER to restore demand. The DRZC will control the additional DER to ensure the generation/load balance is such that the frequency is kept within limits. This DRZC function is called slow balancing.

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

- The level of transient voltages and currents in an islanded network
- Transformer energisation and techniques to mitigate associated generator tripping

- Switchgear and network reactive loading capability
- The accuracy of system modelling
- The benefits of live assurance testing.

Other Comments

The Project outcomes and results contain confidential information and intellectual property rights that cannot be disclosed in this Report due to their proprietary nature. Should the viewer of this Report (“Viewer”) require further details this may be provided on a case by case basis following consultation of all Publishers. In the event such further information is provided each and any Publisher that owns such confidential information or intellectual property rights shall be entitled to request the Viewer enter into terms that govern the sharing of such confidential information and/ or intellectual property rights including where appropriate formal licence terms or confidentiality provisions. Dependent upon the nature of such request the Publishers may be entitled to request a fee from the Viewer in respect of such confidential information or intellectual property rights.

Standards Documents

A detailed review of the technical and commercial codes has also been undertaken and solutions proposed to enable Distribution Restoration. The key codes considered are the Distribution Code (DC), Connection and Use of System Code (CUSC), Balancing and Settlement Code (BSC) and the Distribution Connection and Use of System Agreement (DCUSA). These changes are being progressed via code modifications and issue groups and are currently with Ofgem for approval. A decision is expected by Q4 FY23/24.