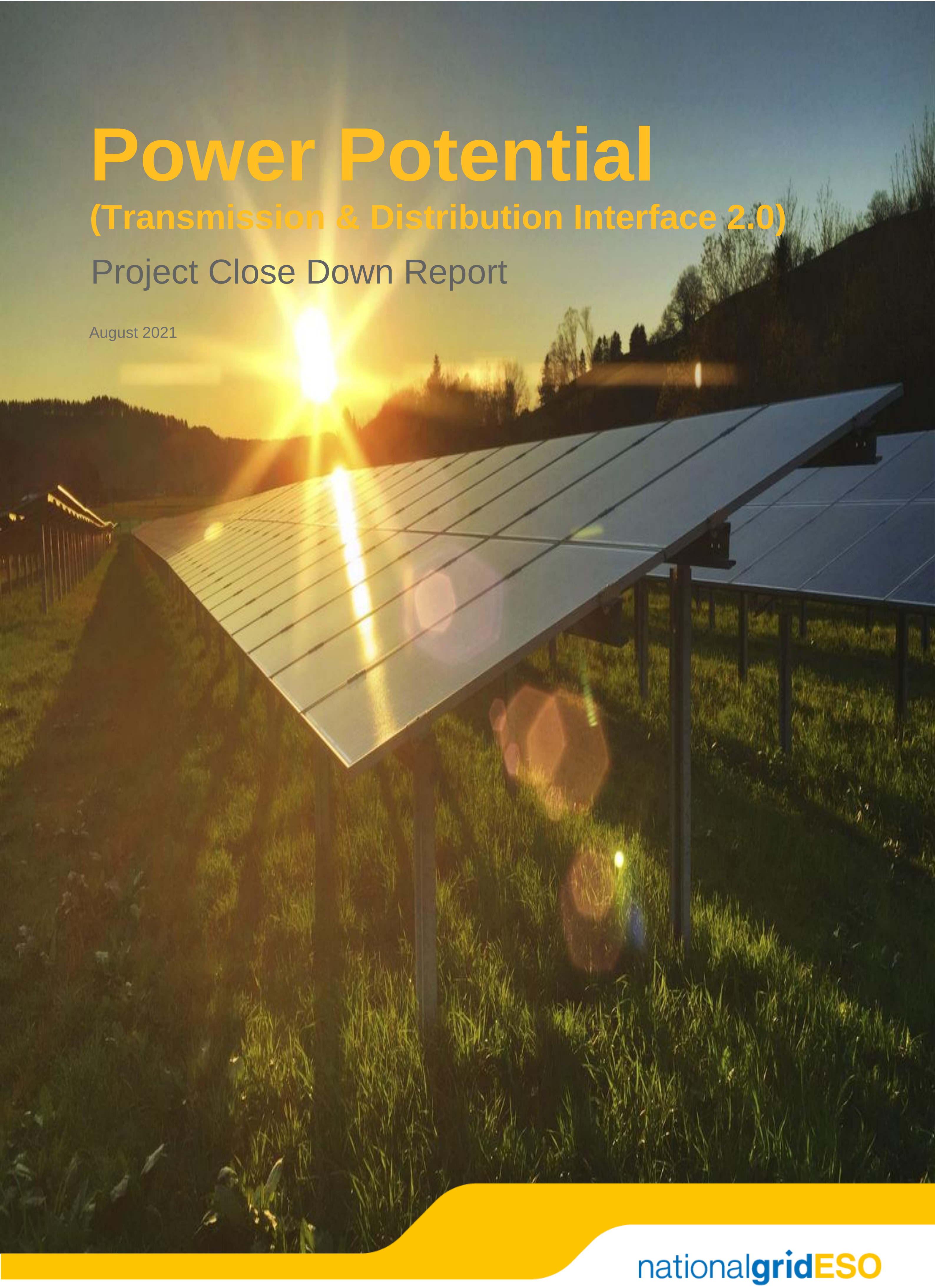

Power Potential

(Transmission & Distribution Interface 2.0)

Project Close Down Report

August 2021

nationalgridESO

Contents

1. Project Background

The South East of England is an ideal location for renewable energy deployment. The topology of the transmission system and generation mix, both in transmission and distribution networks, make this area of the system extremely challenging. National Grid Electricity System Operator (NGESO) is required to maintain the transmission system within normal safe operational limits. NGESO currently uses a wide range of operational measures to make sure that voltage is kept within acceptable stability and compliance margins. These measures also make sure that energy in the system does not exceed equipment ratings. As a result of the growing levels of intermittent renewable generation and interconnectors in the region, National Grid Electricity Transmission is facing increasing operational challenges managing the voltage and thermal limitations for certain network conditions, while still being able to transfer energy to the country's load centres.

The identified constraints include:

- Dynamic voltage stability: requiring reactive power delivery at short notice;
- High voltage: managing the voltage on the network during low load periods; and
- Thermal capacity: potentially leading to generation curtailment during the summer maintenance season.

One of the key roles for the Distribution Network Operator (DNO), besides maintaining security of supply, is to ensure that the network is accessible for all generating customers wishing to connect. Therefore, the constraints upstream in the transmission network have a clear effect on the distribution network and its customers.

To provide voltage support in the South East, increasing reactive compensation is needed. Additionally, thermal constraints require active compensation. DER connected to the distribution network in the area have the potential to provide both reactive and active power services to the transmission system.

Power Potential, also known as Transmission and Distribution Interface 2.0 (TDI 2.0), aimed to demonstrate how NGESO could access DER resources connected to UK Power Networks' network in the South East of England to provide additional operational tools for managing voltage and thermal transmission constraints. The project also intended to assess their relative impact on the cost of solving transmission constraints. The project objective was to create market access for DER to participate in ancillary service provision to NGESO via UK Power Networks, with the services provided by DER alleviating transmission constraints while respecting limits on the distribution network. This would unlock whole systems benefits such as additional network capacity and operational cost savings to customers.

The Power Potential project has trialled a regional reactive power market, the first of its kind in Great Britain, and if transferred to BAU, would help defer network reinforcement needs in the transmission system. The network in the South East of England was selected for the trial since the South Coast transmission network in Sussex and Kent faces particular challenges with management of voltage. This area of the transmission system interfaces with UK Power Networks' distribution system at four Grid Supply points (GSPs) – Canterbury North, Sellindge, Ninfield and Bolney – therefore these GSPs defined the trial region.

The Power Potential project was structured into the following key deliverables:

- A commercial framework, using market forces to create new services provided from DER to NGESO via UK Power Networks.
- A technical and market solution, known as the Distributed Energy Resources Management System (DERMS) installed in UK Power Networks' control room. This enabled DER to offer dynamic reactive power services to National Grid ESO, flexibility for active power re-dispatch to manage transmission constraints and support technical and commercial optimisation and dispatch. It includes gathering bids from DER and presenting an optimised view of the services to National Grid ESO, split by GSP.
- The services offered by DER to the network are coordinated by UK Power Networks, and form part of demonstrating its transition from a DNO to add Distribution System Operator (DSO) roles.

2. Executive Summary

Power Potential is a ground-breaking collaboration between National Grid ESO (NGESO), UK Power Networks and generators on the south coast distribution network. Through the Power Potential project, we have demonstrated a world-first regional reactive power market in a live system trial. We have also verified the principles of a transmission and a distribution system operator enabling Distributed Energy Resources (DER) on the distribution network to deliver dynamic voltage control for transmission constraints. Crucially this has been integrated with operational systems, rather than merely being a proof-of-concept. This four-year £10.1m project has been funded through Ofgem's Network Innovation Competition (NIC) and from contributions by NGESO and UK Power Networks.

The purpose of this close down report is to summarise the Power Potential project – methods, outcomes, modifications, business case, project replication and planned implementation. It outlines the successful completion of the trials in line with the agreed contractual framework and reviews the trial performance and key learning for consideration of transition into a Business-as-Usual (BAU) service.

Background and Objectives

Power Potential aimed to demonstrate how NGESO could access DER resources connected to UK Power Networks' South East network to provide additional operational tools for managing voltage and thermal transmission constraints. The project also intended to assess their relative impact on the cost of solving transmission constraints. The project objective was to create market access for DER to participate in ancillary service provision to NGESO via UK Power Networks, with the services provided by DER alleviating transmission constraints while respecting limits on the distribution network. This would unlock whole systems benefits such as additional network capacity and operational cost savings to customers.

Scope and Outcomes

The Power Potential project has trialled a regional reactive power market, the first of its kind in Great Britain and the world. If transferred to BAU, would help defer network reinforcement needs in the transmission system to increase the availability of capacity for new renewable and battery generators.

The network in the South East of England was selected for the trial since the South Coast transmission network in Sussex and Kent faces particular challenges with management of voltage. This area of the transmission system interfaces with UK Power Networks' distribution system at four Grid Supply points (GSPs) – Canterbury North, Sellindge, Ninfield and Bolney – therefore these GSPs defined the trial region.

The Power Potential project delivered a commercial framework which supported a technical and market solution to enable the services from DER. The project developed technical requirements for DER participation, market procedures and a contractual framework. NGESO and UK Power Networks signed an interoperator agreement to deliver the trials. Following extensive DER customer engagement, five DER signed the framework agreements for trials, and the associated agreements such as a variation to their connection agreement with UK Power Networks. This offered 150 Mvar of service from battery, wind and solar customers (the latter choosing to offer service at night).

After the individual DER commissioning and their Mandatory Technical Trials, four customers proceeded into the end-to-end collective technical and commercial trials. These live trials ran for 20 weeks from October 2020 to March 2021, providing more than 3,700 hours of systems experience. A Distributed Energy Resources Management System (DERMS) enabled day-ahead offer of services by DER, and NGESO procurement of those services against a budget. Based on that day-ahead procurement, we demonstrated automated delivery of dynamic voltage control by DER. DERMS was integrated with National Grid's Platform for Ancillary Services (PAS) and UK Power Networks' PowerOn network management system, providing visibility for both licensees' control engineers. We also successfully ran trials of simultaneous instruction from DERMS for both active and reactive power services to NGESO.

Main learning generated by the Project and its Methods – technical and commercial

By delivering within an agreed safe operational PQ envelope and by ensuring compliance with statutory voltage limits for the distribution networks, the Power Potential approach potentially enables a new source of voltage control from DER.

NGESO, UK Power Networks and the DERMS developer, ZIV Automation, gained insight in how to deliver and operate the systems and processes to enable these services, integrated with other operational systems and processes. This included learning related to system availability, DER delivered response, commissioning processes, the contractual framework and settlements.

Participating DER gained important learning into operation in voltage droop control, how to interface for distribution network control, and how to deliver reactive power services alongside other services such as Firm Frequency Response, Enhanced Frequency Response, Dynamic Containment and any existing active power market obligations.

Based on trial experience, we delivered multiple DERMS improvements and PAS changes. We also identified multiple system and process improvements to facilitate any transition to BAU.

Power Potential was designed as a single dynamic service to meet the dynamic and steady-state use-cases in the bid. Through this project, we have identified that DERMS could enable both DER self-dispatch for a dynamic service and a subsequent enhanced or instructed dynamic service, i.e. each within 2-5s of initiation. However only one out of five DER showed they were capable of fast operation in voltage droop control i.e. to respond in 2-5s and to meet the dynamic service requirement. Noting that the Power Potential technical and commercial design was for a dynamic voltage response, the trial has also verified technically that a steady state performance could be delivered by DER via DERMS.

The project has demonstrated the concept of end-to-end dynamic and steady-state voltage control from DER with a Virtual Power Plant (VPP). The project also provides relevant learning for the development of other future voltage control services from DER. The DERMS integration design, the use of a defined PQ envelope for each DER's service range, and the high-level procurement/market approach could be readily adapted for future reactive power services.

The market element of the Power Potential trial demonstrated the ability of DER to commercially tender and compete to provide a reactive power service within a VPP. It also demonstrated an ability to assess, nominate and instruct reactive power services through VPPs to meet a reactive power requirement. With the implementation of the identified key learnings, it is expected that this could be another option for NGESO to manage dynamic voltage support alongside traditional options (STATCOM/SVC) and transmission connected generators.

Trial participants and members of the project's Regional Market Advisory Panel have endorsed the importance of this project – both as a worthwhile exercise for them to gain practical experience of delivering reactive power services from their plant, but also to build the contracts, requirements, systems and procedures for the future. It is a practical example for the industry of transmission – distribution co-operation, to enable reactive services from DER, and importantly in a market rather than bilateral approach.

Main learning generated by the Project and its Methods – cost benefit analysis

Using a net present value methodology, a cost benefit analysis was carried out on the roll out of Power Potential services from DER against the cost of building transmission-connected STATCOMs for dynamic voltage control. The University of Cambridge analysed the potential benefit of the Method within the trial region. This determined the Power Potential project could save £19.5.m (2018 equivalent) by 2050 in a BAU application in the South East of England. However, several additional types of benefits were also highlighted by University of Cambridge which could be quantified in a future update of the analysis. Such as DER reactive power service volume could also be identified by enabling a PQ envelope rather than up to a power factor limit.

Replication studies were then conducted to determine where else in Great Britain the project's method has the capability to add value. Considering 36 voltage zones, replication was considered in zones with an above average dynamic voltage control requirement as predicted in 2020. The expansion of Power Potential as a dynamic service as trialled, could save energy consumers over £96m by 2050 when rolled out to 19 (out of 36) transmission voltage zones within Great Britain. However, all transmission zones have some dynamic requirement. If the solution were being replicated to more regions, the total benefits could be even higher.

Notably the CBA methodology considered just the long-run transmission-investment alternative, and not the current system costs for maintaining voltage levels on the network from Grid Code compliant generators. The cost to manage voltage requirements in the South East has increased, associated with synchronising generating plant and utilisation costs. The cost has increased from £3.2m in 2018 to £9.2m in 2020.

Power Potential also provided learning for other voltage services, in addition to dynamic voltage control. Any future cost benefit analysis should take into consideration these learnings.

Main learning generated by the Project and its Methods - replication and implementation

The project has identified several areas for improvement and further considerations that will need to be addressed prior to accessing the benefits of DER reactive power capability through a comprehensive Power Potential roll out. Utilising the outcomes of the Power Potential project, UK Power Networks and NGESO are now discussing the next steps to enable voltage-control services from DER to compete with transmission alternatives. This report outlines the physical components, systems and contracts to replicate the service as trialled - across System Operator, a DNO and participating DER. The project partners are identifying the changes to their own systems and processes for a BAU rollout.

NGESO's and UK Power Networks' experience of working together on delivering the Power Potential project has shown it is important that both parties understand each other's ways of working and IT infrastructure needs. The key learnings from Power Potential are being fed into future development work associated with NGESO's voltage Pathfinders and reactive market reform. Further details can be found in the Markets Roadmap to 2025 (https://www.nationalgrideso.com/research-publications/markets-roadmap-2025).

In addition to leveraging the technical and commercial learnings and solutions identified within the trial, we are exploring which elements of functionality and transferable processes from Power Potential can be further developed to fulfil the needs of the Regional Development Programme (RDP). In July 2021 as part of its initial business plan for RIIO-ED2 (the next regulatory period for electricity distribution), UK Power Networks committed to develop the DSO capabilities and to work with NGESO to deliver a business as usual Power Potential offering by 2028.

Achievement of the project's objectives and deliverables

The project successfully met all of its deliverables. This close down report is complemented by a range of "successfully completed delivery reports" on the project website (SDRC 9.1-9.7 covering design, commercial approach, trial readiness, Cost Benefit Analysis (CBA), trials and Distribution System Operator (DSO) risk-reward), academic reports, and project outputs such as contracts, market procedures, technical requirements and technical procedures.

3. Details of the Work Carried Out

The objective of the project was to develop and deliver a live system and commercial/ business framework which would enable a live end-to-end demonstration of how a DSO could enable voltage control services from DER to ESO.

This section details the methods developed for Power Potential and describes the work undertaken to deliver the technical solution and end-to-end services (NGESO-UK Power Networks-DER). The methods as defined in the project bid are as follows:

- A technical solution based on information and communication technologies (ICT), which interacts with all market participants to facilitate the provision of services by the DER to NGESO– a DERMS-based demonstration
- New commercial arrangements between DER, UK Power Networks and NGESO – trial contracts and consideration of how they would develop over time
- Customer and market engagement which ensured that the solution is open to existing and new participants – trial recruitment and engagement, both with trial participants and more widely.

In combination, these provide an example of a coordination framework for secure grid operation, to deliver efficient coordination across ESO and DNO investment planning, operational planning and real-time horizons.

The project was delivered in four broad phases as shown in Figure 1, with the final phase being the live trial demonstration with multiple DER participants. The rest of this section is structured around these four phases.

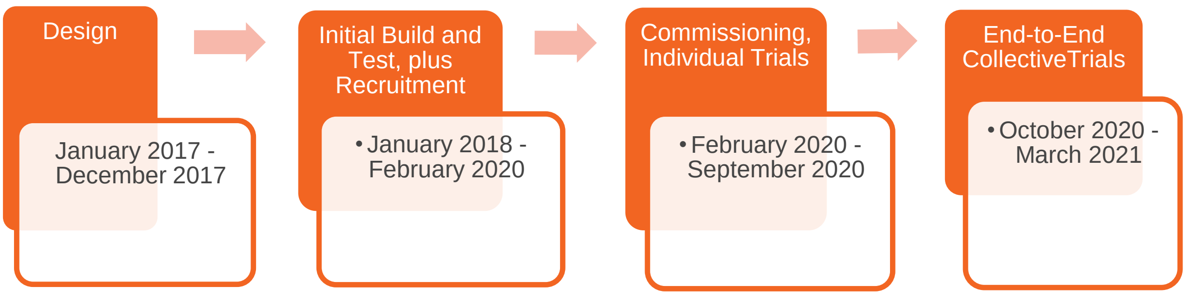

Figure 1 Power Potential delivery phases

Design

Overall Service Design

The overall system design activities were a combination of system design (DERMS and PAS), IS architecture design, system interface design, commercial design (contracts), and business process design. These were delivered by the project partners (NGESO and UK Power Networks as appropriate, seeking relevant internal approvals) working with DERMS supplier ZIV Automation.

To provide context for the explanation of the work carried out to deliver the technical solution and services, including trials, this section provides an overview of the implemented technical design for DER to deliver voltage control services for transmission based on instructions from DERMS.

At a high level, the DERMS solution worked as follows:

- Gather commercial availability, capability and bids from each DER.
- Calculate possible availability of each service at the GSPs (using the effectiveness of DER at the GSP as an input). Once the assessment is complete, a range of service availability and costs are presented to NGESO at day-ahead taking into consideration DER bids, their effectiveness, the DER operational envelope, and what the distribution network could allow at the time of service due to current running arrangements. With this information, NGESO decides the level of services to be procured.
- On the delivery day, NGESO instructs the services to UK Power Networks and the DERMS solution instructs each DER into voltage control and to a voltage set-point as required, while monitoring the response.

The approach implemented for Power Potential's end-to-end trials uses the high-level architecture shown in Figure 2. Each DER participant (bottom right) operates in voltage (droop) control to deliver the services. The DER receives instructions and reports its status to UK Power Networks' systems. This is conducted via an integration from DERMS to the Network Management System (PowerOn), to the site Remote Terminal Unit (RTU), to the customer's local control system or DER controller. Monitoring data is obtained from the site RTU. Further information on this integration across ~20 secure systems and links was provided in SDRC 9.4 (Customer Readiness Report and Performance of the Technical Solution in a Controlled Environment).

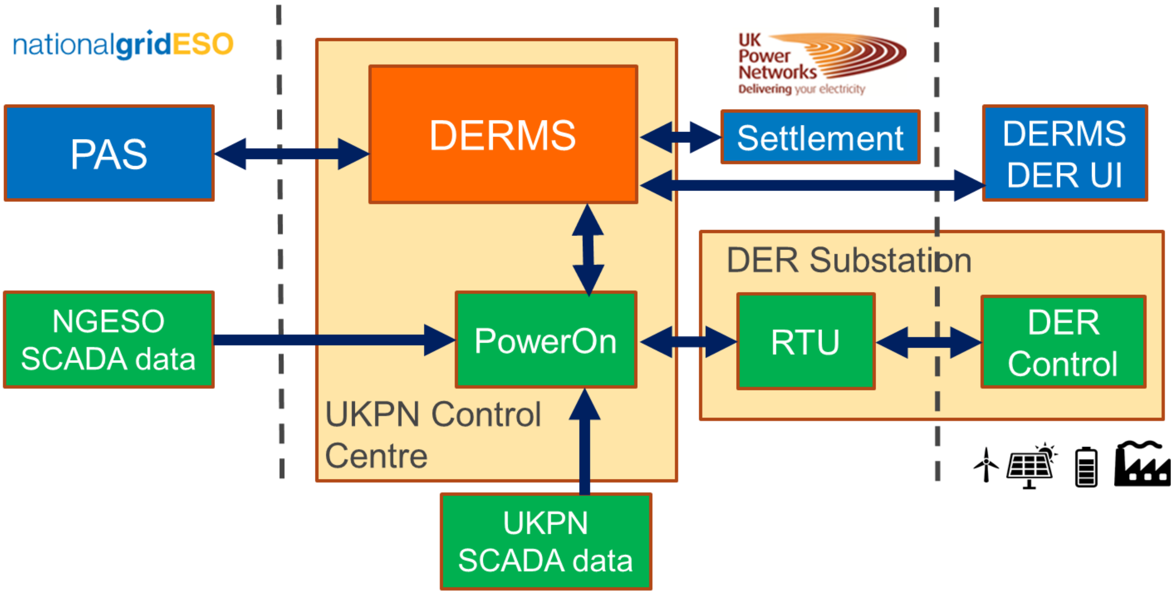

Figure 2 Power Potential technical solution overview including DERMS

In the project, the interface between NGESO and DERMS is through the Platform for Ancillary Services (PAS) system. PAS was a new tool in NGESO's control centre which enables control engineers to dispatch and monitor different services, from frequency and reserve to voltage control solutions.

- DERMS exchanges information with PAS for each 400 kV GSP delivery point during the following timescales:
    - Pre-auction: DERMS sends signals to PAS on service availability and costs (active power and reactive power services) for each 30 minute period over 24 hours;
    - Auction and post-auction: after the auction when the data in DERMS is frozen, PAS enables the control room in NGESO to confirm the service requirements and procured services;
    - Real time: during service delivery, PAS sends instructions to DERMS and receives signals from DERMS on real time service delivery; and
    - Settlements: after service delivery, data from PAS and DERMS are input to the relevant settlement processes at UK Power Networks and NGESO.

DER provide the voltage service based on when they have both offered availability via the DERMS Web Interface (DER UI) and been accepted for service by NGESO – this acceptance is communicated day-ahead of service from the PAS system in NGESO to DERMS and shown on the DERMS Web Interface to DER and UK Power Networks. The PAS-DERMS data exchange is per GSP, representing a VPP of combined DER.

When a DER is accepted to deliver service in a 'service window', DERMS instructs the DER to operate in voltage (droop) control, and sends a voltage set point to the DER. Any difference between the set point and local measured voltage, will cause a reactive power output at the DER – this can affect network voltage to deliver the voltage control service.

DERMS' instructions for response to DER in the VPP, are based on the difference between the target voltage and actual voltage at the GSP. DERMS then monitors and adjusts the issued set points based the transmission requirement and the metering data from the DER site. Instructions from DERMS respect agreed ranges for each

DER for the combination of active power (P) and reactive power (Q) for the site, and statutory voltage limits. These ranges are represented as 'P-Q operational envelopes' and are pre-agreed in the contractual framework for each site during the trial (as described in SDRC 9.4). These maintain a safe and secure distribution network during service delivery.

The allowed P-Q operational envelope of each DER defined the allowed reactive range (Q) at every active power output (P) of each DER, while respecting thermal and voltage constraints on the distribution network. Each DER offered range was studied offline to determine whether it could present any issues for network conditions, and the new operating range was reflected in the trial contracts known as framework agreements (UK Power Networks – DER) and as alteration to the pre-existing connection agreement (UK Power Networks – DER) to increase the reactive power service which could be facilitated securely under DERMS oversight.

The underlying principles of Power Potential required DER to provide reactive power levels beyond those specified in the existing DER connection agreements, which were generally limited to import only at up to 0.95 power factor. As shown in Figure 3, this approach can enable a material increase in the range of reactive service, and the variation in the connection agreement also avoided DER being faced with reactive power charges for operating outside agreed limits.

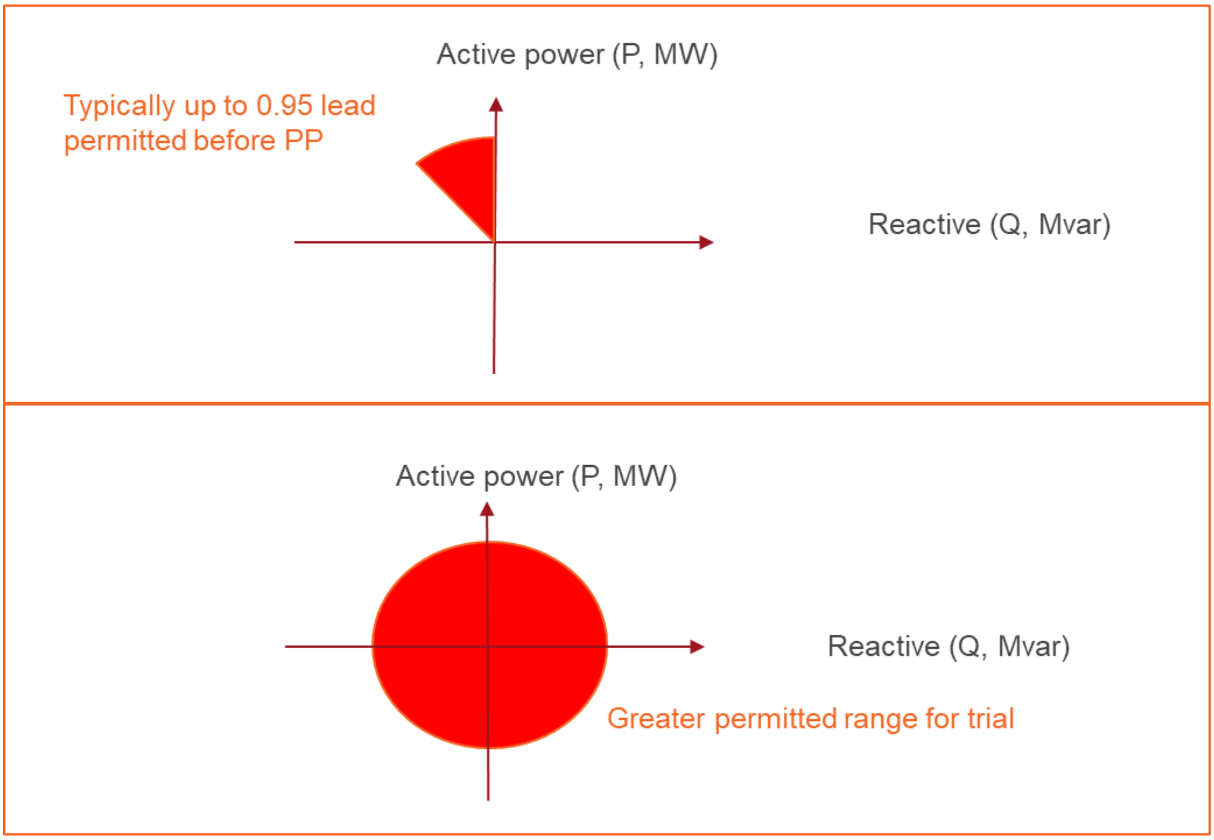

Figure 3 Example of increase in P-Q operational envelope for a battery DER in trial

The DERMS system

At the heart of the system is a technical and market solution known as the Distributed Energy Resources Management System (DERMS), which was integrated in UK Power Networks' control room. This was developed for the project by ZIV Automation The purpose of the DERMS was to enable safe and secure access for NGESO to DER services. More specifically the DERMS enabled DER to offer:

- Dynamic reactive power services to NGESO (full technical and commercial trial)
- Flexibility for active power re-dispatch to manage transmission constraints (short trial, two DER)

At a high level, this involved gathering bids (whether available, expected active power level, availability price, utilisation price) from DER and presenting a view of the available services to NGESO, split by GSP. The services offered by DER to the network were coordinated by UK Power Networks and are an example part of the transition from a DNO to add Distribution System Operator (DSO) roles.

One of the key inputs to enable assessment of DER reactive power availability at the GSP is ‘effectiveness’ (also known as ‘sensitivity’ and the allowed P-Q operational envelope). The flow of reactive power, between DER and GSP can be impeded or diverted by the various reactive components and circuit configurations along the route. UK Power Networks carried out a series of network studies to assess the effectiveness i.e. the expected percentage of reactive power from each DER, reaching each GSP in the trial region.

For the live trials, the effectiveness and P-Q operational envelopes were loaded manually into DERMS as an ‘effectiveness’ factor for each DER and was applied by DERMS to establish a representative service availability at the GSP.

Initial Build and Test, plus Recruitment

Customer recruitment and external stakeholders

The project developed test environments at the DERMS supplier, at UK Power Networks and re-purposed existing test environments at NGESO (for ICCP and PAS). Testing of the DERMS functionality was initially carried in a fully-simulated environment using cloud platforms. Following development of the DERMS pre-production platform, we were able to connect the DERMS to PowerOn (virtual platform separated from the live system) and to a test harness at UK Power Networks’ laboratory. The test harness was developed by the UK Power Networks Operational Telecoms team and comprised working RTUs, with the latest logic configuration and a dummy DER controller. The RTUs were then linked to the virtual PowerOn, providing a complete end-to-end test facility, which could be driven remotely. This proved hugely beneficial during times of restricted practices due to COVID-19. Only once specific test criteria were met could the project apply to the appropriate change control board for permission to deploy and integrate with live operational systems.

The initial live deployment of DERMS was in December 2019 (an information systems infrastructure go-live), following successful completion of both functional and non-functional testing including penetration testing (cyber security). There was a further upgrade in February 2020 which enabled the full signal integration to PowerOn for DER commissioning.

In the report on preparation for trials, SDRC 9.4 we referred to the DERMS Interim and DERMS Full Solution. In this report and in SDRC 9.6, for simplicity we refer to the DERMS solution and a specific upgrade. This is because there were multiple incremental improvements in DERMS informed by trial experience, which were not known at the time of writing the SDRC 9.4 report. In addition, the commercial aspects of the DERMS Full Solution were delivered for live trials, but other aspects designed, such as those relating to network model import, load-flows and active power dispatch from PAS were developed and partially tested but not taken to live trial (see section 6 of this report on required modifications).

It should also be noted that system upgrade and test continued beyond this initial phase in 2018 and 2019. Further upgrades were made in summer 2020 to address issues arising in Mandatory Trial (e.g. assumed voltage droop calculation for DER), then in September 2020 before the end-to-end trials began with PAS. An upgrade was made in December 2020 based on learning from the Wave 1 technical trials and a final upgrade in February 2021 reflecting learning from the Wave 2 commercial trials, which addressed trial interruptions due to repeated temporary loss of connectivity between the PAS and DERMS systems.

Over the Power Potential trials period, the live DERMS solution was upgraded with additional functionality and defect fixes. By focusing development, test and defect resolution on the additional functionality required for the next trial stage (or to resolve issues identified in the previous trial stage) this approach minimised delay to the live system learning. Each version satisfied the needs and readiness for each trial phase. The deployment followed the process and criteria described in the trials report SDRC 9.6, Appendix 2.

Customer recruitment and external stakeholders

The contracts developed are described further in the next section on outcomes. Alongside the technical documentation developed on requirements, test specification and interface schedule, these were the initial foundation of the recruitment and engagement work.

The recruitment and engagement process was jointly led by UK Power Networks and NGESO, in order to shape the project delivery and to recruit DER for the project. Both parties utilised existing relationships with providers within the trial region, through the Connections, Energy Markets and Outage Planning teams at UK Power Networks and the Business Development and Contracts and Settlements team within NGESO.

The team identified possible trial participants who were electrically connected to the trial region through relationships developed through connections and other service delivery, events, mailing lists, the Power Potential project webpages (created for easy access to information) and dedicated mailboxes created to monitor queries. Ongoing engagement was continued throughout the project via the following routes.

- Throughout 2018/19, the project held webinars to keep DER informed of all relevant aspects of the project. The project received significant interest, with 166 participants registering and 66 joining in January 2019. They informed potential trial participants of latest updates, key milestones and shared the timeline for delivery up to the start of the trial. The presentations were published on the project website so those unable to join could catch up in their own time.
- Regional Market Advisory Panel (RMAP) – to provide a formal channel for the project to engage and consult with key stakeholder groups, a Regional Market Advisory Panel (RMAP) was established in early 2018. The Panel was overseen by an independent chair, Dame Fiona Woolf, and was made up of representatives across the industry including Ofgem, the Department for Business, Energy & Industrial Strategy (BEIS), DER, aggregators and their representatives. Panel meetings took place throughout the project, providing valuable feedback on the trial design and terms of the commercial framework, which the project team took on board. Terms of Reference for panel meetings were agreed with members in the first meeting and can be found on the project website[1], along with the minutes from each meeting.
- Surgeries and consultation – held to share, discuss and agree commercial proposition with DER in greater detail.
- Communications strategy to support engagement activity – involved presentations to industry conferences and associations, including the Power Responsive Forum (NGESO), Future Energy conference and Renewable Energy Association's Smart Future Group. Social media coverage was employed to raise the profile of the project online and printed trade publications were circulated at events.

Further details of dissemination events and publications can be found in section 12, and external project outputs in section 13.

DNO Control Room Engagement – key internal stakeholder

The Power Potential methodology was developed to create minimal additional effort for the UK Power Networks control team. Control engineer's involvement during the trials was therefore confined to an initial set of tasks upon service commencement, which included enabling the ICCP links between the DERMS and PowerOn and placing the DER into Power Potential mode. Thereafter responsibilities were for the monitoring of the network for any Power Potential related alarms and indications.

Control engineers were trained and familiarised in the operation of the DERMS user interface within PowerOn. This was carried out in two stages, where a small team of 'super users' were trained initially to carry out specific operations on the live network during commissioning and mandatory technical trials. A wider team of engineers, on each shift team, were later trained in readiness for the full end-to-end trials.

The control team were supported by a Network Operating Procedure (NOP 50 036), developed by UK Power Networks, to cover the operational control by UK Power Networks' Control Engineers of DER operating under Power Potential commissioning and trials.

[1] https://www.nationalgrid.com/uk/investment-and-innovation/innovation/system-operator-innovation/power-potential

Service Introduction – Commissioning and Individual Trials

Prior to commissioning, customers were invited to bring their DER controllers for bench testing at the UK Power Networks' laboratory. Although not compulsory, the main benefit of this approach was to test the integration between the RTU and the DER controller and validate the signals list in a controlled environment and help to identify issues ahead of the site integration. Customer Interface testing at the laboratory was successfully completed for 4 DER with five controller types by August 2019 (detailed in SDRC 9.4).

Commissioning of DER to DERMS

The first element of functional verification of the live system was the commissioning of each DER to DERMS (verifying all signal integration DERMS-PowerOn-RTU-DER on site, dispatch functionality and fail-safes). The second element was a capability test of each DER, in which its operation in voltage droop control to the expected voltage range and speed of response was reviewed.

UK Power Networks successfully commissioned five DER on site. The first DER was fully commissioned in March 2020 and the final DER full commissioning was completed in December 2020.

UK Power Networks documented the end-to-end process in a DER commissioning test procedure (ECP 11-0702 PP DER), specifically for DER which had already been commissioned to PowerOn for normal operation and required additional commissioning of DER to DERMS in accordance with Power Potential requirements. This was carried out and verified on site prior to connecting the participating DER to the live DERMS. The procedure included the associated tele-control pre-commissioning tests, on-site commissioning tests, and checks post-connection (to the live DERMS). The commissioning process was carried out in two stages:

1. Pre-Commissioning – on-site testing and commissioning in the live production environment. This required pre-requisite checking and testing, including the end-to-end integration testing between DERMS – PowerOn – Remote Terminal Unit (RTU) and customer's Local Control System (LCS) on the live environment, before moving on to final commissioning.
2. Full commissioning – confirmation of DER operational services, communications loss and Failsafe actions.

Capability Testing

Each DER participating in the Power Potential trials, was also required to undergo technical capability tests to assess reactive power range and speed of response to changes in voltage set point sent from DERMS. The full extent of the tests is covered in the DER Technical Requirements document on the Power Potential website.

One of the main issues faced, in terms of measuring the fast response times, is the rate at which network data could be captured. UK Power Networks has two mechanisms in place to measure network parameters, both of which pass data through on-site RTUs to a data historian called 'PI'.

1. Analogue metering – widespread existing mechanism feeding into the current Network Management Systems.
2. Power Quality Metering (PQM) – high accuracy metering installed at specific sites (most recent large generation connections) for network performance assessment but not fed back to the Network Management System.

Power Potential employed PQM due its greater accuracy and perceived fast sampling rate. However, following capability testing of the first DER, it was found that although the data was sampled at one second intervals (or less) at the meter, the data reached the 'PI' database sampled at 15 second intervals. Therefore, this proved insufficient for the purposes of the capability test, which required sampling rates of one second to verify the dynamic response.

To overcome this challenge, two alternative methods were used to capture data during subsequent capability tests.

1. UK Power Networks was able to extract the data at one second intervals directly from the PQM servers on site and download to Excel files. This approach required specialist resource and was therefore used when the appropriate UK Power Networks engineers were available.

2. Wireshark – Operational data was recorded directly from the DERMS Front End Processors (FEP) at one second intervals by the system developer (ZIV Automation). Once again, the data was made available in Excel spreadsheets.

Wave 1 Mandatory Technical Trials

The aim of the Wave 1 Mandatory Technical Trials was to demonstrate that DER were technically capable of delivering reactive power services when instructed by the DERMS. DER were only granted access to participate in the other waves of the project and therefore the provision of the service, once they successfully completed the Mandatory Technical Trial.

External guidance and detailed internal test procedures were developed that outlined three reactive power tests, which were conducted as follows:

1. Response to simulated signals; step change in 400kV voltage
2. Response to simulated signals; ramp changes in 400kV voltage
3. Response to 400kV voltage set point changes

The test environment evolved considerably, due to COVID-19 restrictions, from a physical control room and on-site presence, to remote on-line working via Teams, Skype, WebEx, etc. This in turn required careful coordination to ensure key resources were available to perform testing and to resolve potential issues, encountered at any point in the system (test team, control teams, PQM data management, DERMS developer, DER technical representatives, including back up resources).

End-to-End Collective Trials

Wave 1 (Optional) Technical Trials

The aim of the Wave 1 Technical Trials was to demonstrate the end-to-end technical service and analyse the DER responses under DERMS, following different changes in network conditions, directed from NGESO instructions sent from PAS. This part of the trials only applied to the reactive power service, with additional learning potentially driven by system events (unplanned and planned) and not by specific test methods.

After overcoming the additional challenges in delivering DERMS and its integration to the required quality and in achieving DER readiness complicated by COVID-19 (as described in section 6), the trials ran over an eight week period between 15 October to 10 December 2020. The availability hours were modified to still ensure DER could earn up to £45k by being available for a minimum of 987 of the 1,345 hours in the trial, and £36k by being available in voltage control for at least 373 hours. DER indicated their availability via the DERMS web interface. Participation payments were made based on the number of hours DER were available across the total number of hours in the trial.

Network security was not reassessed in real-time against a network model as originally considered at project inception but relied on the P-Q operational envelope. As noted in section 6, there were significant data challenges with validating and integrating a complex network model for daily update into DERMS. Accordingly UK Power Networks developed a process whereby network running constraints were entered manually (day ahead) by 14:00 to reflect any restriction to the P-Q operational envelope due to a change in network running arrangement for the next day, for a given time-period aligning with the commercial service window.

Wave 2 Commercial Trials

The purpose of the Wave 2 Commercial Trials as described in the Market Procedures was to demonstrate the end-to-end service including commercial assessment, and to facilitate "price discovery" from DER by allowing DER to freely bid on both utilisation and availability under a competitive environment. This would allow them to reflect any risk or cost associated with the provision of the reactive power service in the most efficient way. The schedule to provide the reactive power service was from 23:00 on the previous day, to 22:59 on the next day for each day of the trials, according to the Electricity Forward Agreement (EFA) calendar that is used when trading on the electricity market. The EFA calendar is split into four hour windows (or blocks) starting at 23:00.

Payments to DER came from the project budget, so during Wave 2, nominations for service provision were made with the aim of accepting the most economic VPPs whilst operating within the budgetary constraints.

The nomination and assessment processes were undertaken by a constraint analyst at NGESO and was carried out as a day-ahead auction process, broadly as follows:

- At 14:00, the DERMS closes the declaration gate on the DERMS Web Interface, collects bids and provides values, associated with each VPP, taking into consideration network constraints, Mvar availability range (combined lead and lag), expected utilisation adjusted for effectiveness and associated costs. The DERMS sends this to the PAS system for the NGESO assessments team to review.
- At 14:00 NGESO would assess the bids, sent by the DERMS, based on the volumes, prices tendered, estimated utilisation expected and the trial budget. The aim being to procure the largest overall volume across the most economic VPPs.
- The procurement strategy was evaluated against a daily budget spend. This daily spend was derived by considering the total budget, the minimum number of trading hours for the trial and the volume of Mvar available in the market. All VPPs are considered and compared against the daily budget taking into consideration the availability costs and an estimated utilisation level of 85%. If the total cost across all VPP exceeds the budget, then only the most economic VPPs were accepted.
- Before 17:00 NGESO would decide how much of each cost stack, at each GSP, for each service window (EFA Block), it would procure, and communicates this to DERMS.
- At 17:00 the DERMS updates the production schedule responses tab on the web interface confirming if the DER bids were accepted or rejected.
- At the point of nomination all DER receive feedback on the result of their tender. This feedback includes one of seven rejection reason codes if a tender was rejected.
- At the start of the accepted service window, the DER receive from DERMS a ‘V Service Enable’ signal to place the DER in voltage droop control and then DERMS issues a voltage set point, to instruct the injection or absorption of reactive power until DERMS issues a revised set point.

Wave 3 Commercial Trials

The concept of the Wave 3 trials was to utilise participating DER to secure the system reactive power requirement. DER were to submit availability and utilisation prices (as during Wave 2), and these prices would have been compared against alternative actions available to NGESO. This would have included large transmission connected generation that are obliged to provide reactive power services as set out in the Connection and Use of System Code (CUSC). In this case, the budget for Wave 3 payments would have been made directly from NGESO’s balancing services, as per other balancing services and included in BSUoS (Balancing Services Use of System) charges.

This stage of the trials was considered beneficial to provide additional learning to assist with transitioning the outcomes of the Power Potential project into BAU. However, significant delays in starting the trials and consequential budget constraints meant that Wave 3 did not go ahead. This ensured that the project retained its focus on the key objectives of the original bid, which were delivered through the Wave 1 (technical) and Wave 2 (commercial) trials.

Settlements

Production and issue of monthly settlement statements by UK Power Networks involved;

- manual preparation of Wave 1 availability statements (based on hours available),
- manual preparation of Wave 2 statements (based on accepted prices and service delivery) and associated quality check checking of statements, and
- for both waves, issuing of invoices to NGESO, following up on late payment of invoices and issuing self-bill invoices to pay DER.

4. Outcome of the Project

Power Potential has demonstrated that an integrated automated procurement and dispatch approach can be implemented live with operational systems, to deliver end-to-end reactive power services from DER to transmission.

The project enabled us to develop approaches to customer recruitment, contracts, DERMS system delivery, DER commissioning and capability testing and DERMS-DER mandatory trials, which culminated in the successful delivery of the end-to-end collective live technical and commercial trials that ran for 20 weeks from October 2020 to March 2021.

We also ran short trials of simultaneous instruction from DERMS by NGESO for both active and reactive power services – highlighting potential future systems development.

Based on trial experience, we delivered multiple DERMS improvements, for consistency and ease of service delivery, as well as some PAS changes. We also identified multiple system and process improvements for delivery in any BAU transition, e.g. improving visibility of current and past DER availability, both technically and commercially. Valuable learning was gathered at each phase of the project, informing the system development and enhancing delivery of the next stage.

The project and trial would not have been possible without the commitment of the five DER operators who signed the trial contracts and then worked with the project team to prepare and deliver the trials and then to provide feedback as an input to the project reporting. In alphabetical order, these were Gresham House, Lightsource BP, RWE, Vattenfall and Zenobe. Each DER operator made a material contribution to the learning of this project. However, their individual DER sites have been anonymised in the trial reporting.

Contracts and customer recruitment

NGESO and UK Power Networks signed an interoperator agreement to run the trials, in addition to the innovation project delivery contracts. Five DER customers (total 150Mvar reactive range) signed contractual agreements with UK Power Networks to participate in the trials, meeting the minimum recruitment level for trial as defined by the project (5 DER and 40 Mvar). The signed agreements were a DER Framework Agreement, variation to their Connection Agreement, and documentation to set up each DER as a supplier to UK Power Networks including a VAT declaration for issue self-bill invoices to pay the DER.

Commissioning

During commissioning, experience from the first DER highlighted the need for considerable work on the initial checks. For subsequent DER therefore, the commissioning stages were scheduled such that the second stage of full commissioning would only go ahead once pre-commissioning was completed. This was generally then carried out on separate days. This helped to progress the commissioning procedure as well as identify potential risks and learning, prior to connecting DER to the live DERMS as part of the second stage of full commissioning. Furthermore, the experience gained on site provided valuable insight on how to configure the RTU and DER control, which in turn reduced the criticality for laboratory testing of new DER (recommended but not required during the project).

DER Capability and Mandatory Technical Trials

After commissioning DER to the DERMS, capability testing was undertaken to assess reactive power range and speed of response to changes in voltage set point sent from DERMS. Given the requirement for each DER to deliver at least 90% of the maximum reactive range in 2-5 seconds, it is significant that all DER came very close to achieving the requirements, with DER 2, a battery storage unit, achieving full compliance.

DER had raised concerns on their ability to meet the response requirement at the recruitment stage. This led to significant work being done by both the DER and project team to understand and capture relevant learning in this area. In particular, UK Power Networks facilitated testing on DER 1 to test their response time and tune their controller, arranging times for this with network control engineers and outage planners. This resulted in a reduced reactive power range for that customer but allowed the DER to participate in the trials.

The project team agreed to progress DER through the remainder of the trials and continue to monitor performance, in order to provide bid learning in terms of both 'dynamic' and 'steady state' response, as well as wider learning for the project.

The Mandatory Technical trials spanned a number of months (July to December) with five participating DER. Three versions of DERMS were used for Mandatory Technical Trials – 16.7, 18.2.4 and 18.2.6. Release 16.7 addressed an ambiguity in the design in the definition of the voltage droop calculation, so that DER were sent appropriate voltage set points in response to a GSP requirement.

As different DER underwent Mandatory Technical Trials at different times, it spanned more than one release of DERMS. Mandatory Technical trial defects logged underwent triage and resolution for the next release, following the prioritisation and readiness criteria for each version for the trials.

One commissioned DER attempted capability test and Mandatory Technical Trial but was not able to successfully complete and move to the next trial stage. This was due to challenges in managing control with the customer's on-site 33-132kV transformer (stepping up the network voltage) and its tap-changer, and other changes at the generation site as noted in the SDRC 9.6 trials report. However important learning was gained to support participation of such a site in future.

Wave 1 Technical Trials

Wave 1 Technical Trials began in October 2020, where participants submitted their hours of availability (at settlement period granularity) for reactive power for the whole of that period. During Wave 1 Trials, the project could utilise DER while they were armed to provide the Power Potential service at NGESO instruction, and UK Power Networks' coordination. By the end of the trials, there was 100 Mvar of contracted capacity from the four participating DER. The trial delivered 1345 hours of live trial experience.

One of the main observations during the Wave 1 trials, was the increase in the data traffic through the network systems. The DERMS controller speeds were initially reduced as an initial precautionary measure. However, this was resolved with changes to the DERMS integration design (configurable dead band on voltage setpoints and static reactive power limits at RTU), which were implemented prior to Wave 2.

We also observed DER dropping out of service due to over-restrictive active power limits. Therefore, revised limits were agreed with customers, to allow the full range of operability and more consistent service delivery.

Wave 2 Market Trials

Wave 2 trials commenced in January 2021, with participants submitting their service availability on 5 January to start delivery on 6 January at 11:00am. Wave 2 saw competitive bidding among participants, the purpose of this was to facilitate "price discovery" from DER, within the limitations of the trial budget, allowing them to bid freely both utilisation and availability prices, reflecting any risk or cost associated with the provision of the service in the most efficient way.

During the Wave 2 trial period, DER submitted availability and utilisation prices into the DERMS through a web interface at the day-ahead stage. DERMS then provided costs of the aggregated VPP to NGESO, which in turn made a procurement decision based on volume available and accounting for the overall and daily trial budget. This was fed back to the DERMS where DER would see the production schedule responses from 5pm day ahead.

A DER from a VPP which was procured was then committed to being available to provide reactive power services in its accepted service window (for which it received an availability payment). On the following day, at the start of the relevant service window, the DER received voltage set points from DERMS, which could necessitate the injection or absorption of reactive power throughout the window (for which utilisation payments are made, based on the accepted bid of the DER).

Given the unproven nature of the service at the time, the resource procured during Wave 2 was not considered a system resource and was therefore not used to secure the system. This was considered surplus to the network requirements to test the price discovery principle.

The Wave 2 market operated for a total of 1,772 hours, consistent with the planned scale of market hours. To maximise the opportunity available and project learning the auctions were run across both weekdays and weekends. There were also a number of periods where DERMS was unavailable due to upgrade work being undertaken. Results from the trial indicate that the average prices accepted for availability and utilisation were in the range of £1.18 to £4.58 £/Mvar/h and £5.19 to £9.35 £/Mvarh respectively at GSP/VPP level (after application of effectiveness to DER bids, and adjustment for expected volume at GSP). Throughout the trial there were different bidding strategies across the various GSPs. Full details of the commercial results can be found in Section 3 of the SDRC 9.6 report, and price comparison results in Section 5.

Customer Feedback

Feedback from participants in the trial was positive in terms of the level of learning gained and how this could be practically applied to future participation in the provision of balancing services. They gained improved technical understanding of their asset capability, terms and warranties. They were also able to address uncertainties with support from the project team. Participants also highlighted that they were in favour on the approach used for the market in Wave 2 as this was fair, transparent and effective versus a bilateral approach with individual providers.

Technology Readiness Level and Network Performance

The project trialled voltage services from DER as a demonstration, but NGESO did not use these to secure the transmission system or displace any another voltage control actions. Thus, there was no change in network performance attributable to the Method. There was also no adverse effect on distribution network performance.

Between the beginning and end of the project, we assess that the technology readiness level[2] (1-9) of the Method has progressed from

- TRL 4 – Initial development activities with a more commercial application including technology validation and or demonstration in a working environment; to
- TRL 7 – Initial full scale demonstration in a working environment to test and improve technologies so they are ready for commercial deployment.

SDRC 9.6 noted a number of further DERMS and PAS system developments required to transition to a BAU service, and the need for further development of the commercial assessment processes by NGESO to include DER alongside transmission alternatives. Thus, we do not consider that the Method is yet at TRL 8 or 9.

[2] Technology Readiness Level (TRL) as defined on page 80 of the Network Innovation Competition Guidance

5. Performance Compared to Original Project Aims, Objectives and SDRC Deliverables

Page 13 of the original project bid stated that the project aimed to deliver in three key areas:

1. Provide access to dynamic reactive compensation capability from DER within distribution network. The service will be beneficial in terms of avoiding the reinforcement of the transmission network in the future.

2. Provide detailed arrangements for how the transmission and distribution will work together across the interface. Establish the market for accessing the reactive power and also flexibility for active power management.

3. Customer and stakeholder value through learning on coordinated operation of the transmission and distribution networks that is much more efficient than to operate them separately.

The outcomes set out in the previous section confirm that these high-level aims were met. Specific objectives were also identified and delivered as part of the Successful Delivery Reward Criteria (reports) as set out in the following Table 1, with links to the reports. Each report was successfully delivered on time.

Table 1 Status of the project's Successful Delivery Reward Criteria (SDRC)

Successful Delivery Reward Criteria (SDRC)	Comments
SDRC 9.1: **Technical High-Level Design** The high-level design of the technical solution and high-level business processes which will operate the solution. Evidence: • Alternative design options considered and selection criteria • High level design specification • Functional design document • High level business processes • Review of anticipated synergies and conflicts	Completed and submitted on time. Read Here
SDRC 9.2: **Commercial and Detailed Technical Design** **Stage Gate 1** – The agreed detailed technical design (Partner/s, National Grid, UK Power Networks, Customers) and Commercial Framework for the trial. Evidence: • Stakeholder consultation findings • Functional Specification Documents • Finalised Commercial Framework • Detailed Business Processes	Completed and submitted on time. Read Here

Successful Delivery Reward Criteria (SDRC)	Comments
SDRC 9.3: **Commercial Tendering Process Report and Finalised Trials Approach** **Stage Gate 2** – Outline the learnings from the tendering rounds for the reactive power services and the engagement on the active power services. Based on this process and the trials approach, to advise which customers will be utilised during each trial phase and the forecasted effectiveness. Evidence: • Report on tendering approach, including technical and contractual requirements for participation, barriers to entry and measures to alleviate these • Proposed commercial framework and interaction with SO and DNO incentives • Review of technologies and volumes under contract • Initial forecasts of availability and utilisation volumes • Signed commercial contracts • Trials Approach and Methodology	This SDRC was delivered and published on time as planned by NGESO, interpreting 'signed commercial contracts' as requiring signing of the inter-operator agreement between NGESO and UK Power Networks and as described in the SDRC. The agreed inter-operator contract was further revised after the SDRC was submitted, in line with final format of the framework agreement with DER providers.
SDRC 9.4: **Customer Readiness Report and Performance of the Technical Solution in a Controlled Environment** **Stage Gate 3 –** Update on the effort required to ready customers to take part in the trial (technical, business processes, etc.) and the performance of the technical solution in a controlled environment and expected performances in the live environment. Evidence: • Test Report – End-to-End Testing Business Change Implementation Report • Customer Readiness Assessment • Technical Solution – GO / NO-GO Criteria Results • Customer and Business – GO / NO-GO Criteria Results	Completed and submitted on time to the revised delivery date of 30 November 2019. Read here.
SDRC 9.5: **Cost Benefit Analysis** Analysis assessing the financial case for the trial to date and for extending the approach into the future Evidence: Detailed assessment of the costs and benefits of TDI 2.0, to include: • analysis of the net benefit of extending the trial into the future (using Ofgem's CBA framework), replication study assessing the viability of, and case for, extending TDI 2.0 to other DNOs and for providing a wider set of services	Completed and submitted on time for the revised delivery date of 31 March 2019, based on theoretical analysis from the University of Cambridge before the trial. This report was not published due to the risk of distorting participants' bids during the trial. We updated the SDRC 9.5 report in 2021 with additional learning from the trial (accepted bid prices and volumes, and latest view of the delivery and support costs of the technical solution). This updated version of the SDRC 9.5 with the CBA has been submitted and published on 14 May 2021.

Successful Delivery Reward Criteria (SDRC)	Comments
SDRC 9.6: Trials Report **Stage Gate 6** – Trials Report The completion of the trials in line with customer agreements and review of the performance of the trial; the closure of the project (potentially moving into BAU) in line with customer agreements Evidence: • Trials Phase Report including adequacy of contracted volumes to meet requirement, availability/reliability of DER and control system, accuracy of sensitivity and accuracy forecasting, evidence of competitive bidding, evidence of conflicts • Report summarising the financials of each party (subject to DER commercial confidentiality), and in particular the costs incurred by the DNO, the uplift applied to DER bids, and hence the net revenue that the DNO receives • Assessment of scheme design and operation to cover how well it worked, where conflicts arose, and how the governance arrangements performed • Plan for transitioning trial participants into enduring solution	Completed and submitted on time. Read here
SDRC 9.7: DSO risk-reward framework for providing wider system services A paper describing the incentive framework used for the project and recommendations for an enduring incentive framework for an active DSO Evidence • Analysis of the costs, risks and revenues for the services included in the trial • Assessment of mechanism used within the trial and comparison against alternative incentive mechanisms • Assessment of the applicability of these incentive schemes to a DSO providing a broader set of system services and interaction with the wider SO incentives	Completed and submitted on time. Read here

6. Required Modifications to the Planned Approach

This section summarises the modifications to the planned approach, both those noted in changes submitted to Ofgem, and other changes based on project progress and learning.

Non-material changes

A non-material change to an innovation project includes a change in approach to delivering the learning in Ofgem's 'Project Direction', including a change in timescale of less than a year. Through the project delivery, a number of non-material changes were identified to the project plan and shared with Ofgem:

1. **November 2018** – The project switched to a staged system delivery approach to deliver the complex project, and a switch from a year-ahead tender to a day-ahead procurement approach. The project requested to extend report delivery dates and interpretation accordingly, and also to extend the project end-date by four months to April 2020.
2. **August 2019** – Having overcome significant changes in customer recruitment and system test/delivery, this requested a two-month extension to the report on system and customer readiness (SDRC 9.4). This report was delivered by the end of November 2019, reflecting that the initial version of DERMS went live in December 2019.
3. **December 2019** – As part of the annual project report, we confirmed DERMS was live to enable commissioning in the early part of 2020 and therefore revised our expected timeframe for trials. All remaining SDRC dates were adjusted by 11 months, leading to an end date of November 2020 (within the limit for a non-material change).
4. **April 2020** – In our letter to stakeholders detailing the impacts of COVID-19, we reported that one customer had been commissioned in March 2020 prior to the restrictions. However, based on what was known about the pandemic at that time, there was an expected delay of six months to the project. This was based upon commissioning and mandatory trials restarting in June 2020 and a main trials phase of September 2020 to mid-March 2021. The revised project end-date (subject to the trials starting in September) was likely to be May 2021. Thus, the pandemic-related delay took the project from the timescales of a non-material to material change, which was formally requested later as described in the next section. The April 2020 letter also noted that project costs were under review, both due to COVID-19 impact and the previous effect of addressing changes and delays in system and DER readiness.

Material change

There was one material change request to Ofgem on this project, submitted in November 2020 and granted with a change to our project direction in February 2021. This reflected the revised timetable shared with Ofgem and stakeholders in April 2020, just after the beginning of the COVID-19 pandemic. Table 2 below presents what were the agreed timelines before COVID-19 and the material change request, and Table 3 presents the timelines after the change request, with six months added to the reporting timescales. The project end-date formally extended a year to December 2021 as a precaution. However, the project is closing in July 2021, according to the plan indicated in the material change request.

The material change request also requested contingency funding of £393k for the licensees, in return for sacrifice of any potential SDRC reward funding. As noted in section 8, the project was funded both by the project licensees and innovation funding agreed by Ofgem.

Table 2 Planned trial and agreed reporting schedule pre-COVID

Activity	Start	Finish	Duration
Wave 1 Mandatory Trials	**Tuesday 31 March**	**Tuesday 21 April**	**3 weeks**
Transition for integration of additional software functionalities	**Tuesday 21 April**	**Tuesday 28 April**	**1 week**
Wave 1 Optional Trials	**Tuesday 28 April**	**Tuesday 7 July**	**10 weeks**
Software Transition	**Tuesday 7 July**	**Tuesday 14 July**	**1 week**
Wave 2 Commercial Trials	**Tuesday 14 July**	**Friday 30 October**	**15 weeks**
Contractual reporting requirements to Ofgem			
13 November 2020	SDRC 9.5 Cost Benefit Analysis		
13 November 2020	SDRC 9.6 Trials Phase Report		
27 November 2020	SDRC 9.7 DSO risk-reward framework		
27 November 2020	Project end-date		
26 February 2021	Project closure report		

Table 3 New dates for regulatory reporting following the material change request, and actual delivered trial dates after COVID-19 impact

Activity	Start	Finish	Duration
Wave 1 Mandatory Trials	**Tue 14 Jul 2020**	**Mon 24 Aug 2020**	**6 weeks (3 DER)**
	Thu 19 Nov 2020	**Thu 17 Dec 2020**	**4 weeks (2 DER)**
Software Transition	**Fri 25 Sep 2020**	**Tue 29 Sep 2020**	**4 days**
Wave 1 Optional Trials	**Thu 15 Oct 2020**	**Thu 10 Dec 2020**	**8 weeks**
Software Transition	**Mon 14 Dec 2020**	**Wed 16 Dec 2020**	**2 days**
Wave 2 Commercial Trials	**Wed 6 Jan 2021**	**Sat 27 Mar 2021**	**12 weeks**
Contractual reporting requirements to Ofgem			
7 May 2021	SDRC 9.5 Cost Benefit Analysis (update of previous confidential report to a public report, noting previous report met the obligation in the project direction)		
30 April 2021	SDRC 9.6 Trials Phase Report		
15 May 2021	SDRC 9.7 DSO risk-reward framework		
August 2021	Project end-date and project close down report (planned)		
31 December 2021	Project end-date and project close down report (latest date noted in material change request)		

Site commissioning was the aspect most affected by the pandemic restrictions – both for UK Power Networks and DER engineers. As a result, in April 2020, we proposed to

- Keep the duration of Wave 1 Optional Trials at 10 weeks.
- Keep the duration of Wave 2 Market Trials at 15 weeks.
- Keep the original financial commitment to DER the same.

To achieve this, we proposed to freeze the start of Optional and Market trials *until at least* 1 September 2020, maintaining durations by extending the trial timescales *to at least March 2021* and the project end date to at least May 2021. No alteration to the scope of the project was proposed. We revised the approach to go into Optional Trials with one version of the DERMS software, suitable for both Optional and Market Trials. Crucially, new approaches were developed to deliver testing and Mandatory Trials remotely.

The project planning dates in April 2020 were based on the following assumptions:

- System testing activities affected by COVID-19 restart remotely and would complete in April with the upgraded DERMS system live in July or August, without disruption to commissioning,
- The lockdown which suspends commissioning works to be lifted by end May, with restrictions lifted on a phased basis, and

- Return to 'normal' delivery conditions occurs six months after the lockdown restrictions were implemented (23 September).

This plan envisaged that public health restrictions would be lifted in time for sufficient customers to have been both commissioned and passed their Mandatory Trial by the end of August 2020. The upgraded systems were expected to be live in July/August 2020, to enable the collective trials to start in September on a best endeavours basis.

In practice, pandemic restrictions were removed more slowly and partially. After the first national lockdown was lifted, site works to prepare for commissioning were restarted in June 2020, and commissioning restarted for the remaining customers only in August 2020. The first DER Mandatory Trial was run in July 2020. This was successful at third attempt in August 2020 after changes were made both in DERMS and by the DER. The overall duration of the Mandatory Trials was also extended due to COVID – each Mandatory Trial was a half day – but the trials were more spread over time due to the impact on the DER commissioning timescales. The software and interfaces were tested and integrated into UK Power Networks' network in September, ready for the collective trials, and final testing of live integration with PAS was achieved in October.

The main trials phase thus started in October rather than September. This began once three customers were commissioned and ready to join trial, with the remaining two still progressing. As noted earlier, although most DERMS functionality was delivered in September, further upgrades based on project learning were delivered in December 2020 to support Wave 2.

The overall project duration was thus compressed to complete still at the end of March 2021 and with the same financial commitment to DER, but the Wave 1 Optional Trials lasted for eight weeks, a break over the Christmas/New Year period, and the Wave 2 Market Trials for 12 weeks January – March 2021. This updated trial timescale was reflected in the material change request in November 2020 but retaining the same reporting dates and trial end-date as shared with stakeholders in our April 2020 plan.

Since Power Potential is an automatic solution for delivery of DER services to ESO, the second national lockdown did not have significant impacts on the project and no further changes were required. Site commissioning had already been delivered, and remote working practices established for test and trial.

Detailed changes in delivery approach

In the material change request, SDRC 9.4 and SDRC 9.6 reports, we summarised the challenges faced and overcome during the project (in addition to COVID-19). These were in relation to both technical delivery and meeting the minimum customer recruitment level (five DER, 40 Mvar).

In the detailed design, developed during 2017 and 2018 (see SDRC 9.1 and SDRC 9.2), the project set out to deliver the original bid method (2016) in an optimal design for a long-term BAU solution — able to be continually updated from live systems, and expanded to deliver maximum reactive response. This detailed design was ambitious but has ensured that the project has always delivered learning relevant to the potential delivery and expansion of the services post-trial i.e. the value case for the project. However due to the complexity of the combined end-to-end solution, with the budget and time constraints, the project focused the delivered system for live trial on the bid requirements, with learning related to the longer-term value delivered as part of design, development and test. This action has avoided more significant cost impacts and delay to trials, ensuring that we proved an automated solution in line with bid requirements, while delivering offline learning on those longer-term objectives in the detailed design.

In summary, the project delivered against the project scope as defined in the bid, but over a longer timescale, and progressed key elements of its additional scope of design to test stage rather than to live trials. To achieve this, the project Steering Committee approved access to contingency funds to provide the necessary resources.

Specific parts of the design that have provided important learning in test and development, but were de-scoped from implementation in our live trials (and were not specifically named in the original bid scope) are:

1. DERMS using a CIM-compliant model with network and SCADA updates from live PowerOn
2. Power Potential Alarms & Indications in PowerOn
3. Fully Automated Settlement Reporting
4. Systems Backup and Failover.

DERMS using a CIM-compliant model

In the detailed design, for delivering the DERMS work package, the design specified that DERMS would operate with a CIM (Common Information Model) standard compliant internal network model and be able to ingest and use a CIM-compliant network model exported from PowerOn. This would have enabled recalculation of allowed operational envelopes using day-ahead and real-time load flows and could have unlocked further reactive range and improved estimation of available response in the medium-term.

For the trials however, the effects would have been marginal. DER would not have offered larger volumes in trial, and this would have required significant additional effort in creating and validating the new data flows. Accordingly, the trials ran with fixed operational ‘P-Q operational envelopes’ to ensure network security, where conservative network security limits were implemented on the scale of service from each DER (defined in a 'P-Q operational envelope' in the contracts and entered in DERMS). Furthermore, this delivery approach allowed the Wave 1 to Wave 2 system transition to become a low risk activity, avoided a change in contracts and a significant system change part-way through the trial.

It is also noted that the delivered DERMS worked internally based on a CIM-compliant database structure, to allow an extension to use an imported CIM-compliant network model in future.

Power Potential Alarms & Indications in PowerOn

For each DER site, a dedicated screen showing the DER status was developed in PowerOn and gave visibility to UK Power Networks’ Control Engineers. This indicated measurements, services delivered (P, Q, V and power factor), setpoints issued and readbacks from site, RTU operating mode, and operation of all fail-safes tested in DER commissioning). Further developments were identified to provide increased visibility in a BAU service.

Fully Automated Settlement Reporting

A fully automated settlement process had been designed and developed, based on UK Power Networks’ Business Intelligence (BI) system, with data in-feeds from DERMS and a SCADA data historian (PI). Whilst the data in-feed from PI had been established, issues were encountered with the DERMS to BI data transition. Therefore, a semi-automated approach was adopted for live trials, with a manual workaround to capture and transfer the relevant data from DERMS to the settlements process.

Systems Backup and Failover

To provide contingency against system component failure, backup and automatic failover of DERMS, PowerOn and the associated ICCP links was part of the original design. This would have allowed DERMS to failover automatically between the primary control room, the backup site, or even for DERMS and PowerOn to continue operating on different sites.

Manual failover was demonstrated at the end of September 2019. However, in order to fully automate the process, IS developments required a third ‘arbiter’ node to be added to the infrastructure, in order to manage the automatic failover and backups. The increased complexity and cost of this approach outweighed the benefit for the lives trials, i.e. constant monitoring of DER and Systems was already in place by the project team. Hence the backup was delivered but a fully automated failover would need to be tested and implemented for any future BAU service.

7. Significant Variance in Expected Costs

The Power Potential project was awarded funding by Ofgem in 2016 through the Electricity Network Innovation Competition (NIC). It has been funded principally by electricity consumers plus a £1.5m combined initial contribution by the licensees, National Grid ESO and UK Power Networks.

Project income is presented in Table 4. The required changes to project delivery described in Section 6 of this report increased project costs and led to a material change being submitted to Ofgem for approval in November 2020. This requested £393,000 of additional funding from customers, alongside £570,543 of additional funding contribution being made by the project licensees. Table 4 summarises the revised budget approved within the material change. In addition to this, the original budget assumed interest would be generated on the project income received. However the project bank account did not yield interest and licensees have covered this shortfall in income with additional contributions.

The project's final expenditure (£10,083k) was above the original budget (£9,560k), but lower than the revised budget in the material change request (£10,524k), resulting in some unspent project revenue. As such, it was identified that that a portion of the additional £393,000 should be returned to customers.

Drawing on the NIC Governance Document[3] the project's Steering Committee noted the relative size of the additional contributions that consumers and licensees had made to project revenues in the revised budget in 2020, above each of their original contributions to the project. With the lower expenditure, they maintained the proportions of the additional contributions to the budget. The Steering Committee thus approved that £179,535 of the £393,000 funding is 'Returned Project Revenues'. The final project revenue contributions are presented in Table 4.

Table 4 Project budget by source and final contributions

Source	Original budget (2016)	Revised budget (2020)	Expected additional contribution (2020)	Proportion of additional contribution to revised budget	Final total project contribution	Reduction in additional funding
Consumers (Ofgem, NIC)	£7,970,435	£8,363,435	£393,000	40.79%	£8,183,900	£179,535
National Grid ESO	£749,999	£949,689	£199,690	20.72%	£889,852	£59,837
UK Power Networks	£750,090	£1,120,943	£370,853	38.49%	£1,009,727	£111,216
Assumed Interest	£89,589	£89,589		0.00%	£0	
Total	**£9,560,113**	**£10,523,656**	**£963,543**		**£10,083,479**	

Table 5 overleaf summarises actual project expenditure by cost category versus the original budget, and also versus the revised budget submitted to Ofgem as a material change in November 2020. A description of the reasons for variance in expenditure is provided below the table on the following page.

A significant variance is defined as being +-10% of budget. The overall project expenditure was 5% above original budget and 4% below revised budget, so not a significant variance overall. However, there were significant variances in several specific categories. Contractor costs were significantly above budget, whereas equipment, travel & expenses, payments to users and other costs were significantly below.

[3] See clause 8.80 of Electricity Network Innovation Competition Governance Document (Ofgem)

Table 5 Project Expenditure vs Original Budget

NIC Cost Category	Original Budget (2016)	Revised budget (Nov 2020) after material change	Actual expenditure at end of project *(Forecast at 23 June 2021)*	Variance final expenditure v Original Budget (%)	Variance final expenditure v Revised budget (%)
Labour	£3,885,775	£3,879,274	£3,828,063	-1%	-1%
Equipment	£1,448,000	£528,540	£527,052	-64%	0%
Contractors	£1,436,500	£4,223,668	£4,275,083	298%	1%
IT	£915,000	£1,083,738	£876,907	-4%	-19%
IPR costs	0	0	0		
Travel & Expenses	£147,087	£90,000	£66,531	-55%	-26%
Payments to users	£693,000	£567,041	£391,548	-43%	-31%
Contingency	£705,376	0	0	-100%	0%
Decommissioning	0	0	0		
Other	£329,375	£151,395	£118,295	-64%	-22%
Total	**£9,560,113**	**£10,523,656**	**10,083,479**	**5%**	**-4%**

Labour

The net variance is 1% below budget. Increased labour costs, approved by the project Steering Committee from the contingency budget, due to the re-phasing of project delivery activity have been offset as a result of the original budget labelling the two academic contributors' costs and also UK Power Networks' principal IS contractor's time as 'Labour', whilst these costs are reported as actual expenditure under the 'Contractor' classification.

Equipment

Expenditure has been 64% below the original forecast as existing power quality meters were used to improve data collected at DER sites, and across the wider network, data correction approaches including state estimation were chosen for offline investigation in contrast to widespread analogue upgrades (following investigation of the feasibility of recalibration of analogues and identifying that this would be required for the whole network area).

Contractors

Expenditure has been 298% higher than original forecast as the original budget profile labelled the two academic contributors' costs as 'Labour' and UK Power Networks' principal IS contractor as 'Labour', 'IT', 'Travel & Expenses' and 'Other', whilst all these costs are reported as actual expenditure under the 'Contractor' classification. Also, specialist IS skills needed to be resourced externally to address IS integration challenges which have increased costs in this category.

IT

Variance to the original budget: Expenditure 4% lower than forecast as the original budget profile labelled some of UK Power Networks' principal IS contractors' costs as 'IT', whilst these costs are reported as actual expenditure under the 'Contractor' classification. This offset additional IT costs for NGESO, which the project Steering Committee approved from the project's contingency budget.

Variance to the revised budget: NGESO's final IT costs for integration of the project's technology solution with NGESO's Platform for Ancillary Services were lower than forecast in the revised budget, resulting in this cost category's final costs being 19% below revised budget.

Travel and Expenses

Variance to the original budget: Expenditure 55% lower than forecast and the original budget profile labelled some of UK Power Networks' principal IS contractor's costs as 'Travel and Expenses', whilst these costs are reported as actual expenditure under the 'Contractor' classification. The project team's use of digital communications and also the COVID-19 pandemic response has also reduced physical travel costs and increased usage of online meetings. Variance to the revised budget: The revised budget retained some travel and expenses budget to allow for visits to trial sites and to the final dissemination event, in case the pandemic restrictions were lifted before the end of the project. As this did not materialise, the final expenditure on travel and expenses was 26% below the revised budget.

Payments to users

Expenditure 43% below original budget and 31% below revised budget. A lower budget was required to complete trials and achieve learning with the number of DER that participated. Although five DER commissioned, only three DER were eligible to participate from the beginning of the Wave 1 and Wave 2 trials. One DER joined later in Wave 1, and another failed to pass its Mandatory Trial so was not able to progress into the collective trial stage.

In addition, available Wave 2 hours were slightly below the minimum anticipated of 1,800 hours, due to pauses in availability of NGESO procurement team and in availability of DERMS (February upgrade, end March fault for one VPP). In addition, not every DER was available to offer service for the whole of Wave 2, procurement decisions were made based on expecting a higher utilisation factor than achieved in the trials, and some errors were made in procurement decisions. These points provided valuable learning for the project.

Contingency

An initial contingency estimate of nearly £706k was included in the original bid, based on the identified project risks, with a further £393k received as part of the material change request.

All contingency has been allocated, with the project Steering Committee's approval, to delivery activity. The Steering Committee considered specific proposals from the project team for additional funds from the contingency budget, as described in section 6 under *detailed changes in delivery approach*. These included additional resources for:

- NGESO IT time for integrating the project's technology solution with NGESO's Platform for Ancillary Services
- NGESO and UK Power Networks' technical specialist time during the development, testing and integration of the project's technology solution, the Distributed Energy Resources Management System.

Other

Variance to the original budget: Expenditure 64% below original forecast. The project has incurred lower communication costs than anticipated as a result of the COVID-19 pandemic response preventing physical meetings and events and as a result of greater use of lower cost digital communications. The original budget profile also labelled some of UK Power Networks' principal IS contractor's costs as 'Other', whilst these costs are reported as actual expenditure under the 'Contractor' classification.

Variance to revised budget: The revised budget retained some other costs to allow for a physical final dissemination event, in case the pandemic restrictions were lifted before the end of the project. As this did not materialise, the final expenditure on other costs was 22% below the revised budget.

8. Updated Business Case

The business case remains as reported in detail within the SDRC 9.5 Cost Benefit Analysis (CBA) report. As notified to Ofgem in November 2018, the original SDRC 9.5 report was submitted confidentially in March 2019 to Ofgem, but its publication was withheld until the project's commercial trials were completed, to avoid distorting participant behaviour during these trials.

We updated the SDRC 9.5 report to a publicly-available version, with additional learning from the trial (accepted bid prices and volumes). This updated version with the CBA was published on 14 May 2021. The SDRC 9.5 report provides a view of the cost benefit analysis completed by the University of Cambridge on the Power Potential project within the trial region, formed by four GSPs, and its further replication.

Summary of the business case for the trial region

The CBA was calculated using a Net Present Value methodology, compared against the cost of building transmission connected STATCOMs. The University of Cambridge analysed the benefit of the project within the trial region, formed by four GSPs. The analysis has determined the Power Potential project could save £19.5.m (2018 equivalent) by 2050.

The difference in the benefits between the original project bid and the University of Cambridge's cost benefit analysis is a reduction of £5m. The difference comes as a result of the different input data assumptions:

- The University of Cambridge's cost benefit analysis uses an asset annuity duration of 45 years consistent with Ofgem's CBA approach. In the original bid, a value of 20 years for annuity duration was used. At the time that was a standard annuity duration based on transmission owner's asset valuations. The Cambridge University CBA was later updated with Ofgem latest annuity asset duration.
- In the original CBA, the forecasted amount of DER connected in the trial region included DER in size greater than 100 MW. In the University of Cambridge's cost benefit analysis, generators with capacity greater than 100 MW were not considered for contribution to the Power Potential service as they are part of the Obligatory Reactive Power Service.
- The different annuity duration contributes to 60% of the cost difference. The rest of the cost difference comes from not using generators greater than 100 MW or interconnectors.

However, additional types of benefits were highlighted by University of Cambridge, and additional DER reactive power service volume could also be identified. It was also noted that the CBA methodology considers the long-run transmission-investment alternative, and not the current system costs for maintaining voltage levels on the network from Grid Code compliant generators (£9.2m in the trial region in 2020). The cost to manage voltage requirements in the South East has increased, associated with synchronising generating plant and utilisation costs. The total cost has increased from £3.2m in 2018, to £7.3m in 2019 then £9.2m in 2020, as reported in SDRC 9.7.

Note on the replication across GB

Replication studies were conducted to determine where else in Great Britain the project's method has the capability to add value, as described in the SDRC 9.5. From the Two Degrees FES scenario in 2020, the maximum requirement level of 90.64 Gvar was divided across all 36 voltage zones giving an average of 2.5 Gvar per voltage zone. The replicability considered here is based on the zones where dynamic voltage control is required and is calculated on the average reactive requirement of 2.5 Gvar and is valid across the whole CBA study period under the assumption that the requirement on each zone will only worsen (not improve) in future.

This filters the GSP replicability according to above average network requirements for dynamic voltage management needs, for containment and recovery to manage post-disturbance voltage. The expansion of Power Potential as a dynamic service as trialled, could save energy consumers over £96m by 2050 when rolled out to 19 (out of 36) transmission voltage zones within Great Britain.

Sensitivity studies related to the replication threshold of average reactive requirements per voltage zone were not performed, so the potential benefits in the other 17 zones were not assessed. However all transmission zones have some dynamic requirement. If the solution were being replicated to more regions the total benefits could be higher. In any future CBA review, the replication threshold could be considered alongside update of other inputs and inclusion of other factors and benefits presented in SDRC 9.5.

Power Potential also provided additional learning for other voltage services, in addition to dynamic voltage control, which could lead to greater financial benefits in zones across the GB network. However further work would be required to understand and compare this benefit against existing solutions. Therefore, direct replication of these additional benefits was not included at this stage.

9. Lessons Learnt for Future Innovation Projects

This section explains some of the main challenges faced by the project and the approach needed to overcome these challenges, either during the project or going forward.

1. Use distinct names for trial phases without overlap – and test them outside the project team

In hindsight, splitting the Wave 1 Technical Trials into Wave 1 Mandatory and Wave 1 Optional created confusion when explaining to DER and outside the project team. Both Wave 1 Optional and Wave 2 Market trials were optional to participate in, but they were how the DER could earn from the trial and demonstrate the end-to-end service. The lesson here is to test out the naming of trial stages with external stakeholders.

2. Plan for staged delivery when there is complex functionality, integration or dependencies

The initial approach to system delivery (and the associated DERMS delivery and trial design) was to build and test all system functionality in Factory Acceptance Test, then bring all components together in integration test, then pre-production test and take to live trials. This envisaged that there would be one version of DERMS taken to live, capable of supporting all trial functionality. Practically, a staged approach was more suitable (supported by rigorous testing at each stage) with DERMS functionality to be delivered in stages as required by the test/trial requirements, allowing for learning from each test/trial stage and recognising the interaction between function and integration. In addition, readiness for DER commissioning and mandatory trial were spread over months and involved issue resolution with each customer – they could not be scheduled in one fortnight given multiple external dependencies. The learning from this is that for projects which can reasonably be divided into stages with learning between them, then the system delivery, trial plans and contracts (between partners, suppliers and DER) in such projects should be agile and milestone-based, rather than triggering a fixed calendar.

3. Be agile in delivery approach – identify when to combine delivery resources with other innovations and BAU activities

Power Potential was initially scoped as a standalone innovation project, jointly led by the UK Power Networks and NGESO Innovation teams, with support from specialist UK Power Networks resources.

UK Power Networks delivered the DERMS and much of the system architecture integrated with BAU operational systems. However, as the project progressed through the build, test and commissioning phases, other projects within UK Power Networks were increasingly also working on developments in DERMS systems, PowerOn and RTU logic for DER services, most notably the further development of the Flexible Connections scheme (formerly 'Active Network Management'). This saw the opportunities for synergies and shared learning and the delivery structure and resourcing were combined such that specialist UK Power Networks resources could be shared, coordinated and prioritised appropriately for both projects. This included Control Engineers and support systems, operational Telecoms, commissioning team, test management as well as equipment and test facilities. This continued with other related projects in UK Power Networks.

4. Consider the benefits of formal stakeholder groups – Regional Market Advisory Panel (RMAP)

The RMAP was set up by the Power Potential project to bring together a diverse group with expertise throughout the electricity generation and distribution value chain, including Ofgem, BEIS and invited academics, led by a high profile chair (Dame Fiona Woolf). This was a new step for an innovation project, i.e. to engage key stakeholders on an ongoing basis in discussions and challenges. Technical design and its development were explained to the RMAP and learning focused on key commercial themes within the project including BAU provision of voltage services to distribution and associated data, the development of the trial design, payment structures and contractual framework.

5. Review data sharing arrangements, particularly between project partners in different companies

- Develop system data extraction and data sharing capability through the project planning, as part of the technical and business solution. This applies both to real-time operational data and also the data used for trial analysis, performance assessment and settlement.
- Agree and share common methodologies and define all data points e.g. is it an average or a sample or raw data, how are derived values calculated and will they be shared?
- Use a modern file sharing system between companies e.g. SharePoint, to automate data uploads/ downloads into other business information and analytics systems, rather than a file sharing repository. Different systems are being used on new projects.

10. Project Replication

This section covers all physical components and knowledge of the steps, procedures, documentation and training required to replicate the outcomes of the delivered solution. It also touches on future enhancements that could be adopted in a BAU environment.

The design, build, test and implementation of the Power Potential live system was a significant undertaking, with key activities delivered within four dedicated collaborative work streams as shown in Table 4. This structure would need be replicated as part of review for BAU implementation (see next section), replication by another DNO licence area, and for NGESO to enable this in an additional DNO licence area.

Table 4 Objectives of the work streams

Work Stream (WS)	Objectives
WS1 – Technical Solution Delivery	• Architecture Standards • Supplier Selection • Business Requirements Specification • Design (DERMS, PAS, information systems) • Delivery Approach • Subject Matter Expert • PDA Member • System test, live system delivery and change control, commissioning • Technical documentation
WS2 – Commercial	• Design procurement process • Develop contracts • Engage with and sign up participants • Monitor Payments
WS3 – Business Change	• Business Change Strategy and Plan • Change Impact Analysis (CIA) • Organisation Impact Assessment (OIA) • Stakeholder Mapping and Tracking
WS4 – Trials Delivery	• Trials Approach • Customer Engagement • Trial Partner Readiness and On-Boarding • Hyper Care during Trials • Live Trials Delivery – including running Mandatory Trials, Wave 1 and Wave 2 trials

Physical Components of Delivered Technical Solution

Figure 4 illustrates the key Power Potential components and connectivity developed for the project and deployed during the live trials. Table 5 summarises the physical components that were trialled – these are principally DSO systems, with the ESO system shown in grey.

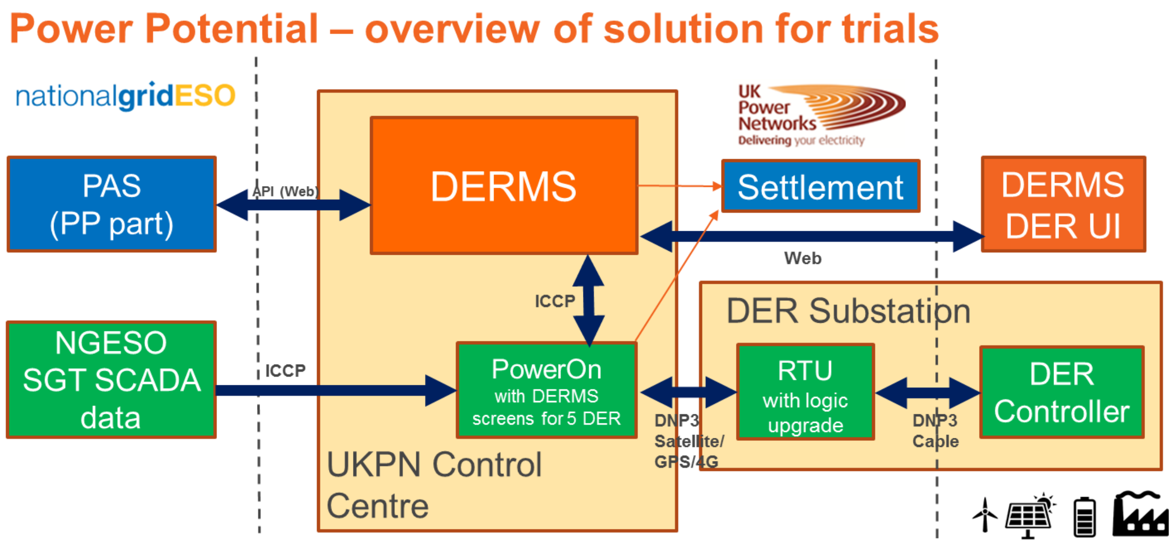

Figure 4 Power Potential architecture for trials

Table 5 Physical components to develop in Power Potential systems for services as trialled

System component	Development required for Power Potential as trialled
DERMS	The DERMS was a newly developed system to enable safe and secure access to DER for NGESO, by gathering bids from DER and presenting a day-ahead and real-time view of the services to NGESO, split by GSP. For the project, this was delivered by ZIV Automation, but this functionality would be available from other vendors' DERMS products. Power Potential employed a mobile visualisation platform for DER, known as 'Grid View' that handled the integration between remote user-interfaces and the CIM Core Database within DERMS.
Including DERMS web interface for DER	Part of DERMS, Grid View DER was a portal provided DER operators the ability to see their technical data, enter and update availability and utilisation pricing (bids) which feed into the Future Availability and Service modules' functions (via CIM Core database); and displays for DER to view their real-time and day-ahead expected service delivery.
and DERMS interfaces for UK Power Networks	Grid View (UK Power Networks) and Cimphony provided UK Power Networks' users with a series of user portals (dashboards) for visualisation, data input and operation through the DERMS. This also facilitated user configurable settings within DERMS, e.g. for customising controller settings for individual DER.
Improvements to the Network Management System – communication and visibility with DERMS and DER	PowerOn is UK Power Networks' network management system, which monitors the network and facilitates network operation. A Power Potential interface developed (by UK Power Networks' Control Systems Automation team) within PowerOn Advantage for control engineers to interact with the DERMS via dedicated screens for each of the five DER, based on a common template Communications between PowerOn and DERMS was via an ICCP connection. A separate user interface was implemented within PowerOn for control engineers to enable/disable the connection directly from the control room.
UK Power Networks' RTUs with logic upgrade	The existing GE T3300 RTUs were reconfigured with new logic developed by GE to support DER controller interface via DNP3 and processing of DER/network data for Power Potential. This included a development of the logic to support a 'floating' data type, as opposed to using scaling factors on integer data, as reflected in the DER Interface Schedule.

System component	Development required for Power Potential as trialled
ICCP link between NGESO IEMS system and DNO Network Management System (PowerOn)	A communications link was required to transfer NGESO SCADA data relating to the GSP to PowerOn (the selected GSP voltages and also active and reactive power flows). Power Potential was able to benefit from the Inter Control Centre Protocol set up in a previous innovation project, but this may be a new requirement. Real-time SCADA data is transmitted over an ICCP link that connects the UK Power Networks and NGESO control rooms. Initial set up costs of an ICCP link are of the order of £1.5m.
GSP metering and NGESO IEMS SCADA system	Voltage (including definition of the selected voltage for control purposes to be used by DERMS), active power and reactive power at each GSP
Settlement system	A settlement system for calculating statements based on service delivery – the project developed a Business Intelligence (BI) system, with data in-feeds from DERMS and PI data historian. A process also needs to be designed and developed for invoicing by the DNO to NGESO and payment of services to DER.
Power Potential component of PAS	The NGESO main interface with DERMS is the PAS. PAS was designed to receive volume availability and cost from DERMS, for each Power Potential service at the GSP level. It also allowed NGESO control room engineers to provide instructions for the different services, in real-time.
PAS-DERMS web interface	The NGESO dispatch signal/instruction interface was initially designed to be an ICCP connection between PAS and PowerOn. However, a design decision had been made to use a Web Service interface between PAS and DERMS. The reason being, NGESO currently use this type of link with other service providers (e.g. STOR) and using this existing communication method allowed the project to progress without significant communication changes to the NGESO system.

Service On-boarding Requirements

Design Governance – the DERMS systems design and its integration would need to be created and approved by the DNO's control systems and operational telecoms team. Similarly, the overall IS architecture (logical architecture and physical architecture) would need to be created and approved for integration with operational systems, in accordance with all security policies. In UK Power Networks, this required IS design approval at an Architecture Review Board, and changes to live systems (post-testing) were taken through change-control governance before implementation. A key consideration in the UK Power Networks design was whether to use on-premises or cloud-hosted infrastructure; this decision would reflect each DNO's security policies and legacy infrastructure. Similar design governance is required for NGESO and its PAS/ICCP infrastructure.

Testing Strategy would need to be considered at each stage of the development and the environment on which the testing is conducted, e.g. simulated cloud-based platform, off-line pre-production environment or live system testing. The following lists the standard set of testing deployed throughout the build and test phase of the project.

Pre-requisites

- Validate requirements definition and agree
- Define test scenarios and test cases for each requirement
- Agree the logical flow of dynamic testing
- Agree datasets to be used
- Agree exit entry criteria for each test

Active Testing

- Pre-release testing – DERMS supplier's own testing on its test environment, prior to release to the DNO

- Factory Acceptance Testing (FAT) – Supplier's own testing of software, but installed on the UK Power Networks test environment with simulation of network load and DER response
- System Integration Testing (SIT) – Validating the Power Potential end-to-end functionality (Functional and Commercial) with full integration of all supporting systems
- User Acceptance testing (UAT) – Verification of Power Potential solution against existing output from systems. Note: SIT and UAT can be run as a combined phase
- Non Functional testing (NFT) – To validate server/application related functions like backup & restore, data storage, user access, penetration/security, performance, resilience, and scheduled housekeeping tasks
- Operational Acceptance Testing (OAT) – Validation of processes to support Power Potential in live production including all interfaces with other systems. Where live connection/running is not possible the pre-prod environment or live snapshot simulations are considered/adopted.
- Regression testing throughout – To ensure that no errors or problems have been introduced and existing unchanged areas of the application/service still function as they did prior to the changes. This test is not a specific phase and will be conducted on supplier's and DNO's recommendation or at any time during the project lifecycle. Typically run after a major release.
- Service review post go-live – an initial trials or tuning phase in which any oscillations in service delivery can be identified and addressed by DERMS controller tuning, and during which GSP and DER voltage dead bands and actual operating ranges can be reviewed.

Documentation requirements

The following are examples of the documentation requirements to on-board DER for their service delivery and are available on the project website. However, these would need to be reviewed and adopted by a DNO seeking to replicate the service. Business processes and customer journeys would need to be developed for the adopting organisation (as noted in SDRC 9.4).

- **Introductory information to explain the service and commissioning journey** – presentations, factsheets
- **Technical Characteristics Submission Spreadsheet** – to gather initial information from a DER as part of expressing interest in the service – either for existing connections or as part of the new connections process
- **DER Technical Requirements** – to highlight the communication and control performance requirements for DER
- **DER Interface Schedule** – to document and explain the signals between the UK Power Networks RTU and DER controller, including an additional information on how to set up the DNP3 Protocol configuration for each signal. These signals are needed to integrate the DER controller with the Power Potential solution via an RTU device.
- **Commissioning procedure** – bespoke procedure detailing the methodology and testing requirements for placing the Power Potential system into live operation, confirming compliance with the technical requirements and interface schedule. In addition to the DNO's commissioning activity, a capability assessment for compliance (**DER Test Specification**) and potentially elements of Mandatory Trial may also need to be agreed with NGESO.
- **Market Procedures** – jointly defined between the DNO and NGESO
- **Market Reporting** – see template in appendix 3 of SDRC 9.6
- Contractual agreements
    - **Framework Agreement** – detailing the terms of the service and settlement
    - **Variation to the connection agreement** – to expand the operational PQ envelope during service delivery with DERMS beyond the usual power factor mode restrictions, and ensure DER are not penalised for reactive power service delivery
    - **Registration to receive payment** – financial supplier registration, VAT declaration for automatic payment by DNO to DER in a self-bill arrangement

Assessment Prior to DER Commissioning

Desktop assessment per DER – In order to secure the distribution network, an assessment is required by a DNO's infrastructure planning team (or an external consultancy provided with the DNO's planning network model e.g. DigSILENT PowerFactory) to determine the necessary limitations that should be applied to each DER to prevent overloading or out-of-range voltages on the distribution network. This would include:

- Assessment of equipment thermal loading, operating voltages and step voltage changes when the distribution network is in its fully intact configuration
- Development of PQ and VQ capability curves for each DER included in the Power Potential trial to prevent loading and voltage limits being exceeded in the distribution network.

This provides inputs to the PQ envelope in the DER Framework Agreement and the variation to the DER connection agreement.

UK Power Networks' site assessment per DER – required to ensure site and equipment suitability and to plan the DNO's site works prior to commissioning.

- Is the RTU type suitable for upgraded logic? If not, a more modern RTU type may be required.
- Identify location for DER controller to confirm connection type to RTU – fibre optic or CAT5 cable
- Site communications (Satellite or 4G) – important to establish adequate data transfer between RTU and network management systems (PowerOn) – satellite preferred.

Support customers in their own site assessment per DER – Can the plant or its inverters operate in voltage control at the required speed of response? Is the customer's controller suitable for communications against the defined interface schedule? One of the Power Potential project's technical requirements was for DER to communicate to UK Power Networks via Distribution Network Protocol (DNP3). This protocol is widely used within the utilities industry and is also used by UK Power Networks for its SCADA system. Upon speaking with potential participants, those DER with a controller that was already in use, were using the Modbus protocol at their site. This meant that in order to participate, DER needed to check if their current site controller was compatible with DNP3. Some DER were required to purchase a DNP3 module, whilst others had bespoke equipment which required coding.

Bench testing per DER – optional for individual DER, but part of system testing that de-risks site commissioning

- Laboratory space, customer coordination and test expertise to liaise with DER customers to test integration of their DER controller against a test RTU, to check compliance with the DER interface schedule, and/or to review a DER's own test results. Laboratory space would also be used for DERMS-PowerOn-RTU-DER controller testing before service introduction.

Business Capability and Training Requirements

Key DNO business areas are required to adapt to new processes and roles:

- Control Room able to monitor networks and responding to DERMS alerts and messages. Additional training for use of new DERMS interface screens in PowerOn to operate and manage the system, particularly during commissioning of new DER for the service. Control team training needs to consider shift team availability for both training and 24/7 service coverage.
- Infrastructure Planning and Outage Planning teams utilise DERMS data for outage and network planning activities
- IS and Control System Automation teams manage and support IT and DERMS infrastructure
- DERMS operational and day to day management of the service, including settlements.
- Providing DER user training and user administration for the DERMS/DER Web interface.
- Customer liaison role set up to provide both technical and commercial support and guidance to customers throughout the project. For example, discussing progress on site works, training on user interface, organising resource for commissioning and trials, sign contracts, gather and address customer feedback.

NGESO

- NGESO Business users and Electricity Network Control Centre were trained to use PAS for day ahead procurement. PAS platform is also used in BAU for procuring balancing services.

Anticipated BAU Costs of Replicating the Project Outcome

Many of the systems, processes and functionality developments, for a DNO to enable Power Potential, are in common with other developments that a DNO is likely to be making, to facilitate flexible connections (non-firm access rights) and flexibility services. These are part of the developments that all DNOs are taking as they progress into Distribution System Operator roles, particularly in the next regulatory period from 2023.

Specifically, to implement Power Potential as an example of a flexibility service, required developments include a DERMS with functionalities for DER reactive power services and integrated communications with NGESO systems, and a DSO market platform (either within DERMS as in the Power Potential project or separately). A DSO would need to create capabilities to on-board new DER for reactive flexibility services, both technically and also commercially to sign and manage DER contracts. There would also be ongoing costs to host and manage the systems, and to run settlements. The initial and ongoing additional costs will depend on a DNO's development stage on its DSO journey, which links to NGESO have already been implemented, and the development status of the other DER flexibility services that it is enabling and whether it already has a DER communications solution and contractual framework.

In our SDRC 9.5 report on cost-benefit analysis, we noted indicative costs, to implement a DERMS solution once designed, of £1.2m per licence area, plus £0.33m per GSP, and £0.3m p.a. of DSO operational costs. However, it was also noted that a DERMS solution should support multiple smart network solutions, not just reactive power and voltage control services to transmission. Potentially 10% of these costs would be attributed to a Power Potential service as trialled.

We also noted in SDRC 9.5 and the SDRC 9.6 report on trials that the project had demonstrated the principles of voltage control by DER, but that further design and system changes would be required for a BAU solution. The systems and processes from the trial are being used to support future discussions on an extension to the scope of Regional Development Programmes to include reactive power services from DER in the development of DERMS for RDP. Depending on the chosen scope of changes, progressing these alterations could cost ~£0.6-1.0m to the DSO in its first application (design, develop, test, operational validation), in addition to the costs noted above. There could also be additional costs for any DNO licence area without existing communications with NGESO – an existing ICCP link for transfer of GSP metering data (~£1.5m), or a PAS-DERMS web services link for commercial data exchange and service instructions with NGESO (~£0.6m). However again these costs may be shared with other services such as reverse power-flow monitoring and control at GSPs and other services in the Regional Development Programmes.

From NGESO's perspective, while some work will need to be done on developing the PAS ASDP, the required infrastructure for the replication of the project outcome would need to be embedded in the existing balancing services procurement processes. Table 6**Error! Reference source not found.** provides a detailed explanation on improvements required for successful process integration, including estimated work time required and corresponding costs.

Table 6 Detailed explanation on improvements required for successful process integration with NGESO systems

Task No.	Task Description	Development Effort (Days)	Overall Implementation Cost (£)
1	Ancillary Services Dispatch Platform (ASDP) application was designed and developed for Windows 7 OS. As all the systems in National Grid ESO are migrating to Windows 10, ASDP system has also been asked to upgrade the application to make it compatible with W10. Currently the services. Frequency Response (FR) and Short-term operating reserve (STOR) in ASDP are getting migrated to work with Windows 10. Whereas, ASDP Power Potential is currently not getting upgraded as the services are turned off and not operational. Hence, changes are required to make Power Potential service compatible with Windows 10.	5-7	39,000
2	As per the Power Potential requirement for the trial, ASDP solution was designed to have at-most 4 GSPs in a single screen for dispatch and monitoring purposes by control room users. ASDP PP solution is not scalable to have more than 4 GSPs currently. Any changes in this regard will require complete re-design and coding of the solution.	15+	113,000
3	ASDP application pool recycle issues caused during the trials with the DERMS system are due to technical limitations of the IIS servers. For this, some changes are getting implemented in the Load Balancer to minimise the Application Pool reset issue that was happening during PP Trials. Changes are due for R9 release in July. This has to be tested with DERMS to ensure smooth operations.	2-3	16,000
4	As part of the initial requirement, 3 Roles of users are requested for Power Potential trials. ASDP supports only 1 user for each of 3 roles of PP namely, An Analyst, Trader and Transmission System Engineer (TSE). If we need to accommodate a greater number of users for PP in production, an infrastructure upgrade may be required to the existing servers of ASDP.	NA	NA
5	ASDP currently generates 3 reports that are consumed manually by the settlements team and default payments were made manually as it was intended for trials. Changes required at ASDP to enhance and automate the settlement interface to the settlement system (MSM). This might involve development of the settlement application for PP.	8-12	68,000
6	Clock change fixes are anticipated for Availability and Nomination functionalities and this has to be fixed before we productionise the system.	15+	113,000
7	During the last phase of the trials, there was request from PP users to have to have dynamic configurable parameters like Dead band, Voltage Target, Droop, etc., which was not possible with the ASDP application. ASDP PP system is built for trial purposes and the range was specified according to the trial requirement. Any deviations on this requires a change in the ASDP code.	8-12	68,000
8	Few performance glitches were noticed in the Power Potential trial period and would require a performance improvement for PP screens in ASDP application. Mainly to enhance the Nomination and Dispatch screens.	5-7	39,000
9	Enhancements to improve supportability of the Power Potential application for BAU support.	2-3	16,000
10	Proper Business Continuity plan should be agreed and implemented with business in case of any outages in the system. This might require efforts from DERMS side as well.	8-12	68,000

Task No.	Task Description	Development Effort (Days)	Overall Implementation Cost (£)
11	Changes required at Consistent Data & Systems Architecture (CDSA) to re-enable the schedulers related to Power Potential and enable the existing GSP IDs in production. If the GSP IDs are new from those were used in the trials, then a data load and script preparation is required at ASDP and the same has to be configured at CDSA/WSO2 (enterprise integration).	10-15	85,000

Cost Details:
The overall implementation cost against each item mentioned above also includes fixed cost which is contributed towards Project support, Management, Environment support activities etc along with Development and Test Costs.

As there are no detailed non-functional requirements agreed yet, so no Infrastructure uplift cost has been included. For example, the requirement on maximum number of requests, VDI (remoted desktop) for business, response times (less than 2mins), etc.

This cost above is for implementation and does NOT include Run The Business (RTB) Cost

Intellectual Property Rights (IPR)

The project recognises the importance of knowledge sharing as a vehicle for widespread adoption of its learnings to facilitate replication. The project conformed to IPR requirements for Network Innovation Competition[4] projects, and this has been formalised via the collaboration agreement between the partners and the supply contract with ZIV Automation that reflect acceptance of these arrangements in full. No intellectual property has been formally registered in relation to the project e.g. as a patent.

The newly generated intellectual property from the project, also known as Foreground IPR, is documented in the projects' annual reports (for the reports please see Table 13) and the Foreground IPR is summarised in Table 7. Many of these documents are already publicly available in the key learning documents as listed in section 13. Consistent with the NIC governance, other documentation can be made available on request to other network licensees with appropriate context and redaction of confidential information.

Table 7 Summary of intellectual property generated by the project

Workstream	Intellectual Property Description	IPR Owner
WS1	TDI 2.0 solution requirement specification document	UK Power Networks
WS1/2	DER Operating Characteristics document	NGESO and UK Power Networks
Project	Project Handbook	NGESO and UK Power Networks
WS1/2	Use cases definition	NGESO and UK Power Networks
WS2	Communication and DER Engagement Plan	NGESO and UK Power Networks
WS1/2/3	SDRC 9.1 Detailed design	NGESO and UK Power Networks
WS1/2	Functional and non-functional requirements for TDI 2.0 technology solution	NGESO and UK Power Networks
WS1/2/3	SDRC 9.2 Detailed design	NGESO and UK Power Networks
WS1/2/3	SDRC 9.3 Commercial Tendering Process Report and Finalised Trials Approach	NGESO and UK Power Networks
WS1	Detailed Design for the DERMS Solution	ZIV Automation, UK Power Networks and NGESO

[4] See section 9 of Electricity Network Innovation Competition Governance Document (Ofgem)

Workstream	Intellectual Property Description	IPR Owner
WS1	Supplementary Detailed Design for the DERMS solution	ZIV Automation, UK Power Networks and NGESO
WS1	Logical Architecture Design, Physical Architecture Design	UK Power Networks
WS1/2	SDRC 9.5 Cost Benefit Analysis Report	NGESO, UK Power Networks and Cambridge University
WS1	Power Potential Test Strategy	UK Power Networks
WS1/2/3	SDRC 9.4 Customer Readiness Report and Performance of the Technical Solution in a Controlled Environment	NGESO and UK Power Networks
WS4	Mandatory Trials guideline document	NGESO and UK Power Networks
WS4	Optional Trials guideline document	NGESO and UK Power Networks
WS4	Mandatory Trials test specifications, procedures and guidance	NGESO and UK Power Networks
WS1	Power Potential commissioning requirements and procedure, control engineers Network Operating Procedure	UK Power Networks
WS1/WS2	DERMS DER web interface user guide	UK Power Networks and ZIV Automation
WS1	DERMS manual	ZIV Automation
WS4	SDRC 9.6 – Trials Report	NGESO and UK Power Networks
WS2/3	SDRC 9.7 – DSO risk-reward framework for providing wider system services	NGESO and UK Power Networks

Confirmation of Service Design for Replication and Development into BAU

During the Power Potential trials, a number of detailed developments were identified for the systems and administrative mechanisms surrounding Power Potential's transition to BAU, as noted in SDRC9.6. Power Potential was trialled as one dynamic voltage service which includes both dynamic post-fault and steady-state, lead and lag, and with day-ahead procurement by VPP based on a GSP. However, the high-level service requirements would need confirmed prior to creating a replication plan in a particular region, key points to consider for the systems, commercial framework and processes would be:

- Is the only NGESO requirement for dynamic voltage control (post-fault)? In this case, DER reactive response will be reserved for large changes in GSP voltage, which will affect the chosen 'base' reactive power value of the VPP as noted earlier in the Outcomes section.
    - This would also reduce the utilisation. In the trials, NGESO used a uniform 85% utilisation factor as an input to the day-ahead commercial assessment of what to procure, although actual utilisation in trials was less than 20%. Reducing the base reactive power value to reserve response for post-fault response would have reduced this further. Thus, a new approach would need to be defined to provide the utilisation factor inputs to the commercial assessment, whether to vary this by time and VPP, and to make this transparent to the market.
- Is there a need for a static service (sustained high voltage challenge)? Future static reactive services from DER could be enabled by DERMS by an adaptation of what was trialled – instructing for reactive power rather than for voltage. This would require corresponding assumptions for utilisation factor.
- Is there a distribution network requirement for voltage control services? Again, this would require an adaptation to what was trialled in Power Potential
- What is the geographical requirement? Power Potential trials were based commercially and technically on dynamic voltage control per GSP, for four GSPs in the South Eastern Power Networks (SPN). However, this could be expanded to a wider system area, with different procurement zones and technical zones within.
- What is the optimal procurement timescale? Day-ahead or a longer-timescale?

Potential Future Alternative System Architecture

Further development of our thinking since SDRC 9.6 has focused on system communications design. For the live trials, Power Potential employed a communications design where DERMS dispatched instructions to DER via PowerOn and RTU. The benefit of using this type of approach is where network operations are required, such as switching or opening circuit breakers as part of failsafe actions. However, this required significant RTU development to ensure appropriate logic configuration, and development of PowerOn to provide a user interface for the control team, and then careful on-site commissioning activities (and the associated preparation by UK Power Networks and the DER).

However, for Power Potential, such failsafe actions, involving circuit breaker operations, are not necessarily required if the service is only delivered from customers with a 'firm' or unrestricted network connection and within a defined acceptable P-Q operational envelope. Therefore, future developments within UK Power Networks could use cloud-based API dispatch platform in place of the trialled communications approach for these customers and services, with an RTU-based approach for customers with non-firm connections. An API approach to a reactive power flexibility service could be easier for DER and UK Power Networks to implement. This approach could be used by either individual DER or by aggregators.

Figure 5 illustrates this potential alternative approach, which is now being considered by UK Power Networks, with DERMS using a separate dispatch platform for instruction of DER by API.

Figure 5 also shows a potential separation from DERMS of a DSO market platform for commercial activities, such as DER registration, service definition, settlements, DER service availabilities, with DERMS indicating actual service availability from the network and making dispatch decisions, and communication with NGESO for both day ahead and within day. It is envisaged that such an approach would also provide greater flexibility to incorporate additional services.

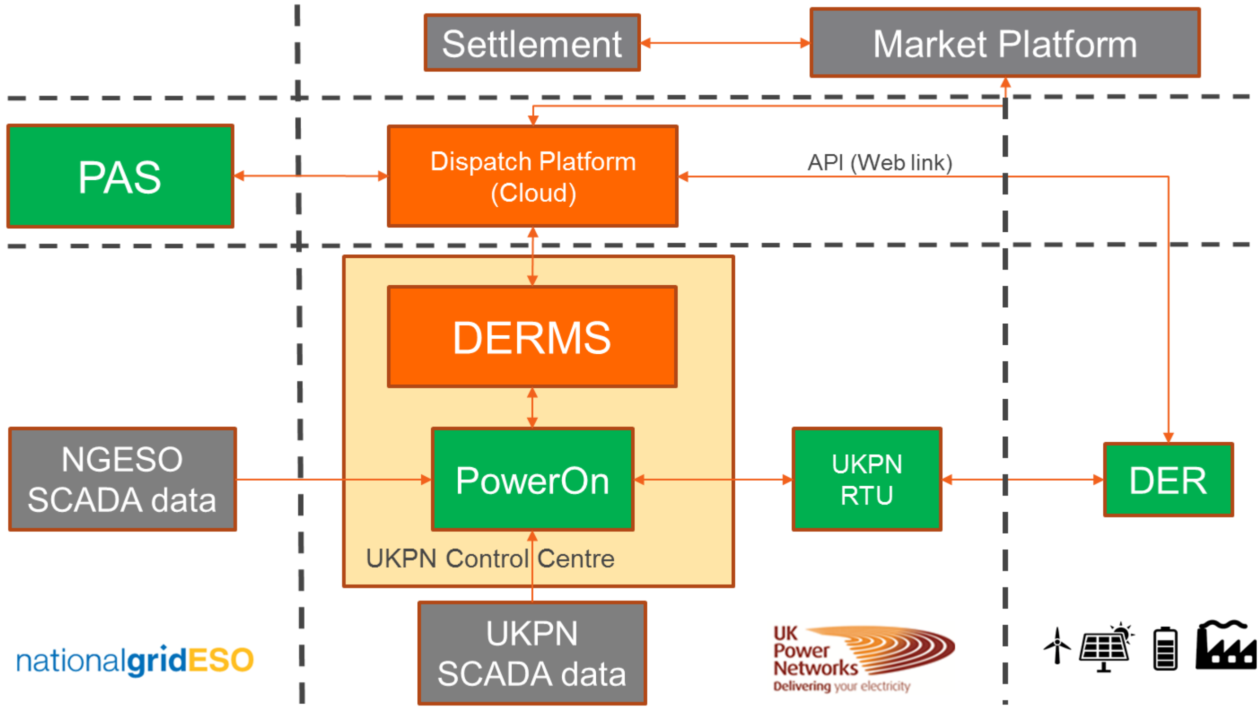

Figure 5 Alternative implementation of Power Potential using a DERMS, a cloud-based dispatch architecture and separate DSO market platform

Although not in the scope of the Power Potential trial, there is clear stakeholder interest in developing an aggregator interface, and furthermore, scoping interaction with aggregators is a learning objective from the original project bid. Therefore, the project has conducted a feasibility study that provides an assessment of available methods and potential design considerations to develop a DER aggregator interface in the context of the project's requirements. The outcome of the feasibility study has been summarised in the "DER Aggregator Interface to DERMS – Feasibility Study".

11. Planned Implementation

Power Potential has demonstrated the concepts of an end-to-end dynamic voltage control service while also resolving the steady state voltage cases on the network. This is a new means of procuring reactive power services using DER capability within a competitive market environment. By introducing additional Mvar capability onto the system, DER could provide a positive impact when used to displace or delay the installation of network assets for the provision of reactive power services. This translates into lower Transmission Network Use of System (TNUoS) charges, paid by demand and generators. However, the project has also identified a number of areas for improvement that need to be addressed prior to accessing the benefits of DER reactive power capability through a potential roll out of the concepts trialled within the project. SDRC 9.6 (Trials Report) outlines in detail the key learning from the project that needs to be considered in a planned implementation approach towards BAU.

This section therefore summarises these areas in terms of Power Potential roll-out for a future BAU service, (including further work before the method can be implemented), actions on licensees and non-network licensee parties, and provides recommendations on exploiting outcomes of the project further.

Note that beyond upgrade of RTUs and integration of power quality metering, implementation of Power Potential does not require modification of the electrical network. However, it does require development and implementation of operational and non-operational IT systems and processes to support the services, as outlined in section 10 (Project Replication).

Implementation of Outcomes

To leverage the technical and commercial learnings and solutions identified within the trial, the project partners are keen to explore which elements of functionality and transferable processes from Power Potential can be further developed to fulfil the needs, and expand the future scope of, the UK Power Networks and NGESO Regional Development Programme (RDP).

RDPs are initiatives that look at the complex interactions between distribution and transmission networks in areas with large amounts of transmission connections and DER, which are leading to a capacity shortfall. The RDPs that are being developed by NGESO and DNOs to facilitate whole system electricity coordination, are implementing similar data exchange between transmission and distribution in parallel with associated ENA Open Networks work streams. More information is available on the RDP website;

https://www.nationalgrideso.com/research-publications/regional-development-programmes

The RDPs are designed to look at the whole electricity system and assess a variety of options to resolve specific network needs. They can be triggered by customer connections or wider changes to the electricity system. The south-coast RDP between NGESO and UK Power Networks is developing new markets for transmission thermal constraint management services in a similar geographic location to Power Potential. This will involve the development of a co-ordinated IT solution that will deliver:

- Visibility and data exchange in both directions to facilitate efficient service coordination.
- Management of DER to allow constraints on transmission and distribution networks to be managed efficiently
- A coordinated procurement and dispatch methodology allowing DER to participate in new markets and ensure that we have identified the cheapest solution for the GB consumer
- Co-ordination and service conflict resolution methodologies

The RDP has been running for five years, and NGESO and UK Power Networks' further experience working on Power Potential will be extremely relevant in delivering the future RDP developments ensuring that both parties understand ways of working and IT infrastructure needs. While the RDP's primary focus is on thermal (MW) constraint management, there may also be opportunity as the RDP develops to build in voltage management. The triggers for doing so will be a specific service requirement emerging from customer connections (both distribution and transmission connected), general requirements which are identified through the network planning process or developments in wider reactive power and voltage control markets, currently being progressed under NGESO's "Future of Reactive" work.

Any future work to take forward the outcomes from the Power Potential project needs to consider several key areas of improvement to facilitate the service.

Technical Service Development for End to-End Service Implementation into BAU

Below are the technical aspects of the dynamic voltage control service that, from an NGESO perspective on end-to-end service, are required improvements that need to be taken into further consideration before service transition to BAU.

- **DER compliance** – DER will need to pass a set of compliance tests in order to demonstrate compliance with dynamic voltage service requirements with respect to speed of response and operation in voltage droop control mode. Reactive power compliance for service providers has been established in the NGESO Pathfinder projects which could be utilised for dynamic voltage service. Further details regarding NGESO Pathfinder projects can be found in the Markets Roadmap to 2025 (https://www.nationalgrideso.com/research-publications/markets-roadmap-2025).
- **Dynamic voltage response** – It is essential that for BAU the Q-base design is changed so the VPP service at the GSP is as expected by the NGESO compliance team. For dynamic voltage control, the transmission-connected plants receive a voltage set point from ENCC control engineer and they proportionally react to changes of the system voltage. Furthermore, all transmission-connected plants are providing a proportional dynamic voltage service so currently the performance of DER in the Power Potential project cannot be compared to transmission plant. The changes would need to be done in the DERMS design and fully tested before implementation. Several solutions to achieve a proportional response from DER were considered during the trials which are further outlined in SDRC 9.6 in section 6.2.3 ("GSP Q base enhancement"). One of these solutions was to mimic the correct Q base by changing the GSP droop slope equal to the effective capacity of the DER at the GSP. This would instruct a full DER response in a post-fault scenario to cause at least a 4% voltage change at the GSP. The assumed utilisation factor of the service would need to be adjusted accordingly.
- **Avoiding instability or oscillation in the service** – any dispatch requests from PAS to DERMS that result in oscillations needs to be addressed as the response needs to remain stable when issuing GSP voltage set points close to the dead band or passing through zero voltage reference. Introducing the service for BAU with the upgraded DERMS implementation, would still require a period of observation to allow DERMS controller tuning per GSP as performed in the Wave 2 trial.
- **Reliability of the service** – clear indication of when the GSP is not available (PAS-DERMS communication issue, DERMS error, DER problem or other system issues or outages) ahead or at time of service dispatch. That will allow ENCC not to progress with instructions due to the system errors and will also allow NGESO to procure required services in time from an alternative provider to secure the system.
- **Uptake of the service** – if DER and Mvar volumes remain small, they will have a minimal impact on the transmission system and there is a risk that the service will not be prioritised for dispatch compared to alternative available options. Consequently, it is important to have higher volumes from VPPs that will have an impact on the transmission system.
- **Dispatch strategy and modelling** – currently NGESO develops a reactive power strategy/requirement on a regional basis and not per GSP. For BAU, dynamic voltage control needs to be analysed to determine if the best approach is to have dynamic voltage control per GSP/VPP basis or if there are synergies with a more regional approach. Modelling of VPP banding would be required in offline and online modelling tools so assess service requirements.

Commercial Framework Development

As part of the Power Potential trial, the project captured some key aspects of the commercial arrangements, framework and processes within the trial that may require further consideration to be able to support any transition to an enduring service and market liquidity.

- **Contractual Framework** – The contractual design to access reactive power services from DER within the trial was structured as an Inter Operator agreement between NGESO and UK Power Networks alongside a Framework Agreement between UK Power Networks and the DER. Learnings from this arrangement are currently being used to develop RDP arrangements. Further consideration may be required on the evolution of the contractual framework for reactive power services procured from/through the DNO, i.e. for whole system services. Variations may be determined by the scope of changes to the range of commercial and technical issues identified within the trial and evolving reactive power needs. Further consideration of the contractual framework is provided in the SDRC 9.7 report "DSO risk-reward framework".

- **Service Procurement/ Funding** – A transition of the service to BAU will require that the procurement of the service is subject to the framework laid down in Condition C16 of the Transmission licences. Ofgem approval is also required for it to be classed as a balancing service and funded through Balancing Services use of Systems (BSUoS).
- **DER Contractual Agreement** – Review of the DER contractual framework is required to ensure it would be more closely aligned to standard balancing services terms. Particularly in areas such as performance monitoring, penalties for non-delivery and service payment structure to ensure greater value is being placed in the right areas to drive the right pricing and procurement strategies.
- **Conflict of services** – Any conflict between the dispatch of this service with other DNO services needs to be considered to understand implications and interactions with other projects such as RDP and project TERRE.
- **Obligations to/by DNO** – Roles and responsibilities need to be defined in consistency with other DNO approaches as it is expected that DNOs will become increasingly active with greater volumes of DER connected.
- **Level playing field** – Further review is required to determine what steps need to be taken to ensure a level playing field between market options in providing reactive power services (embedded DER and transmission connected generators).
- **Procurement timeframe (day-ahead auctions)** – The current procurement process and timeframe should be reviewed to understand if this is the best option for the procurement of reactive power service from DER. Procurement timescales will be considered as part of the future of reactive power market reform which is aimed at designing an effective market based solution for future reactive power procurement based on the technical, commercial and market analysis. Additional consideration also needs to be given to implementing a fully automated nomination and assessment process.
- **Aggregation** – There may need to be further trialling/work to be done on how aggregation may be able to support access to embedded generation for the provision of reactive power services. The project developed initial design considerations, but did not trial this.
- **Commercial Assessment zone across multiple GSPs** – Procurement for the trial was against a target cost and daily budget cap with an assumed utilisation factor, though the DER could bid commercially. In the future VPP could be commercially assessed regionally (multi-GSP or zone as defined by NGESO for its voltage assessments) rather than at GSP level, to increase the effective market size and avoid disregarding the effectiveness of DER at a GSP which is not its 'primary GSP'.
- **Evaluation of DER utilisation vs alternative sources of voltage control at transmission level** – The proposed Wave 3 trial extension may have provided insight into how DER could compete technically and commercially against alternative voltage control options available to NGESO. However, Wave 3 was not taken forward due to time and budget constraints, thus we see potential for a further demonstration to inform the market using the new updated DERMS platform, as a stage in the introduction of a BAU service.

UK Power Networks' Integrated Service Development

UK Power Networks sees the DER reactive and active power service development for transmission in Power Potential, as part of a suite of future flexibility products, managed by its DSO function, which the future DERMS platform would facilitate (illustrated in Figure 6).

In future developments of DERMS, Power Potential services could work alongside flexible connections (previously known as ANM), flexibility services (demand reduction), developments as part of the Regional Development Programme (N-3 operational tripping schemes, and future commercial developments), flexibility services for electric vehicle fleet (Optimise Prime), network reconfiguration (Active Response) and generation constraint management. The Power Potential services could also be expanded for voltage control on the distribution network rather than just as a service to NGESO. This is a future requirement, not currently a business need.

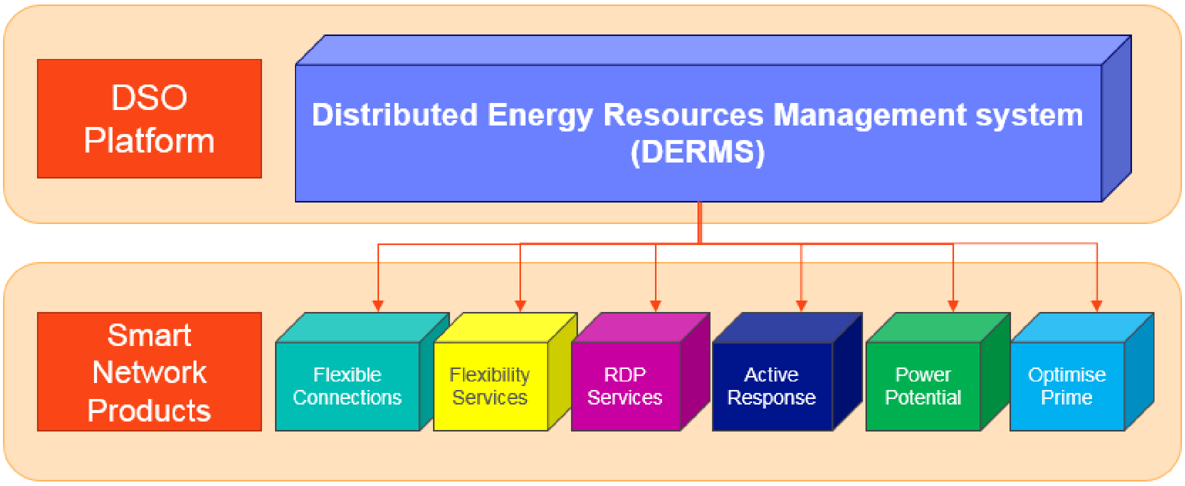

Figure 6 Future view of suite of smart network products enabled by a DERMS DSO platform

UK Power Networks' views on Power Potential reactive power services

The Power Potential trial has provided the proof-of-concept for dynamic and steady-state voltage services. However, UK Power Networks notes the challenges with DER capability for dynamic service in regarding their speed of response (see section see section 4 of this report "Outcomes of the project"). It is also noted that while Power Potential was trialled as a single dynamic service, the integration, the use of a defined PQ envelope for the service range of each DER, and the high-level procurement/market approach could be applicable to either a dynamic or steady-state case, and it could be readily adapted for a static service with a direct request of reactive power.

The DERMS approach is different to other initiatives in procuring reactive power services from DER. Power Potential accessed a service from a whole DER P-Q operational envelope with no power factor restrictions to create a VPP. It also enabled day-ahead market procurement by service window, rather than longer-term procurement.

Thus UK Power Networks sees the opportunity for the Power Potential concept to be split in future into two separately-procured products with different control algorithms to enable wider DER participation – a dynamic and steady-state service (lead and lag range procured, similar to the trialled product) and an additional static service to be developed (lead and/or lag purchased as required). This indicates an opportunity for the Power Potential concept to be used as a basis and foundation for any future reactive power services to NGESO.

Power Potential as part of the RIIO-ED2 business plan

On 1 July 2021, UK Power Networks submitted its initial business plan for the next regulatory period for electricity distribution (2023-2028) to Ofgem's challenge group. Commitment WS6 is to work with the ESO to expand the Power Potential trial to be a business as usual offering across the EPN and SPN (Eastern and South Eastern) regions by 2028. The project trial area was part of SPN. This will be a world-first large scale rollout of a whole system reactive power management. The Eastern and South Eastern regions cover the planned expansion of the RDP regions. The business plan commits UK Power Networks to developing the capabilities to facilitate Power Potential services from DER, both technically and commercially, for NGESO to consider in its future procurement and dispatch processes.

12. Learning Dissemination

Dissemination of the Power Potential project learnings focused on both external mechanisms to raise awareness with key stakeholders and audiences within the industry. The key mechanisms used throughout the project are listed below. Further details of dissemination events, Regional Market Advisory Panel meetings, conferences, trial technical and commercial participation documents can be found on the project's website (https://www.nationalgrideso.com/future-energy/projects/power-potential).

Based on stakeholder feedback at the December 2019 Regional Market Advisory Panel, between December 2019 and July 2021, email newsletters as shown in Figure 7 were issued to project stakeholders including the trial participants, internal stakeholders and Regional Market Advisory Panel members. The frequency varied from weekly to biweekly to monthly depending on the project stage – covering trial readiness, trial progress and then reporting on learning.

Issue 22

Dear RMAP members and others,

Our end-end Wave 1 Optional Technical Trials started on Wednesday 14th October, with the service delivery beginning on Thursday 15th October for eight weeks. We are capturing monitoring data daily from all sites and have created logs of events and issues for the trial reporting.

Figure 7 Newsletter updates to main project stakeholders

There was also a wider industry mailing list which was used to provide occasional project updates from 2017 to early 2020, and once the trials completed in 2021. LinkedIn was also used to highlight key project milestones and events. Table 8 lists the awards received by the Power Potential project.

Table 8 Power Potential awards

Award	Status
Real IT Awards **'Best Use of New and Emerging Technology Award' in the innovation category (2018)**	Submission was shortlisted
13th British Renewable Energy Awards **'Smart Energy Award' (2018)**	Submission was shortlisted
14th British Renewable Energy Awards **'Sustainability Award' (2019)**	Submission was shortlisted
Energy Efficiency Awards **– South East Region, 'Infrastructure Innovation' (2019)**	Winner
National Technology Awards '**'IoT project of the year' (2019)**	Winner

Stakeholder events

A number of events have been held since the outset of the project, where learning and experience have been shared and feedback received. In addition to the project publications and the two project showcase events described later, Table 9 presents a list of the events from the start of the project, with the shaded events being examples where the project has targeted knowledge transfer to other GB network licensees. Figure 8 is an example of Power Potential coverage at industry conferences and social media platforms.

Figure 8 Dr Ali Reza Ahmadi, UK Power Networks and Dr Biljana Stojkovska, NGESO, presenting on Power Potential at the Future Networks Conference 2018, with examples of supporting social media coverage on LinkedIn

Table 9 Events for dissemination and feedback

Event date	Event name	Event description
26 February 2017	Denver – Grid Modernisation	Conference
21 March 2017	International Utility Working Group (IUWG)	Working Group
7 April 2017	Kent Active System Management event	Event
10 October 2017	Bilateral meeting with TSO Swiss Grid and company AXPO Power, Switzerland,	Sharing experience on reactive power and visiting the AXPO control room
18 October 2017	IET CIGRE Conference, Birmingham	Presentation of the major Power Potential concept and way of approaching the project solution. Conference presentation was to reach to wider engineering group.
7 November 2017	STA Storage Seminar	Presentation to the group of storage providers and expanding how the Power Potential principle can be applied for new technologies
6 December 2017 **16/17 October 2018** **31 October 2019** **8 December 2020**	Low Carbon Networks and Innovation Conference (4 events)	Annual knowledge dissemination event for the electricity and gas energy network operators. It offers a single platform where delegates can access the major learnings from the largest regulator-funded innovation projects in the country – the Network Innovation Competitions (NICs) and Network Innovation Allowance (NIA).

Event date	Event name	Event description
11 January 2018	Power Responsive forum	Power Responsive is an NGESO stakeholder-led programme, facilitated by National Grid ESO, to stimulate increased participation in the different forms of flexible technology, such as Demand Side Response (DSR), storage, and distributed generation.
February 2018	Bilateral meeting with TSO RTE	Exchange experience on managing and using reactive power for system voltage control with French system operator
1 February 2018	Large Scale Asset Management Working group	Working group
27 February 2018	UK Power Networks DER customer forum	Customer forum
March 2018	IDC CONFERENCE, Pan European Executive summit, "Mastering the Art of Utilities Transformation Think Big, Start Small, and Scale Fast	Presenting Power Potential innovative concept to wider European stakeholder
18 April 2018	Future Networks conference	Oral presentation to the wider transmission and distribution companies on the initial results of Power Potential
2 May 2018	All Energy Conference	The UK's largest low carbon energy and full supply chain renewables event for private and public sector energy end users.
16 May 2018	Renewable Energy Association event	An event held by the largest renewable energy and clean technology trade association in the UK encompassing all of renewables industry in the United Kingdom.
10 October 2018	IET's international conference on Renewable Power Generation (Lyngby, Denmark)	Presentation of published paper "Enhancing transmission and distribution system coordination and control in Great Britain using power services from distributed energy resources"
23 October 2018	Flexibility Forum – exhibitor stand	A Power Responsive hosted forum as an opportunity for individuals and organisations interested in demand side flexibility to learn more about the opportunities available to them, and the work that is being carried out across the industry to address barriers to entry and increase participation in flexibility markets.
30 October 2018	Power Potential Industry Event	First showcase event of the Power Potential. Great attendance, with speakers talking about importance of Power Potential for future development of the reactive market, to importance of inclusion and diversity in the sector. Event was used to discuss many technical and commercial questions that stakeholders have about Power Potential.
7 November 2018	CIGRE webinar	A dedicated project webinar to outline of Power Potential objectives and benefits, trial phases, technical IT solution
2019	Overview of Power Potential experience to SSE (DERMS focus)	UK Power Networks hosted SSE and ZIV to provide an overview to SSE of how Power Potential was being delivered from a distribution network perspective.

Event date	Event name	Event description
2 October 2019	Smart Grid Flexibility Forum	A forum for leading energy transition specialists for the latest solutions to the strategic, commercial and technical issues surrounding the development of a more flexible energy system.
February 20019	Solar Trade Association	Presenting Power Potential to solar providers in GB, in order to increase the number of new technology participation
21 February 2020	*ENA Electricity Innovation Forum	An event aimed at sharing the latest knowledge and findings from the networks leading energy innovation projects – presentation on DSO perspective on enabling Power Potential
4 March 2020	CIGRE webinar	A dedicated project webinar to share DER testing and commissioning strategies, technical trial activities and how the service will be dispatched, price discovery phase and how the market would be run
20 April 2020	CMS Cameron McKenna	Power Potential and ESO Operability system challenges
24 May 2020	CMS Cameron McKenna	Power Potential and other flexibility services enabled by UK Power Networks
8 July 2020	Ofgem	Invited presentation on Power Potential and Distributed ReStart
23 June 2021	Overview to BEIS	Brief overview of key learning from project, in context of future learning for innovation projects in flexibility

Consultations

The project sought specific feedback in informal consultations at key points to shape the project delivery and learning.

Table 10 Informal consultations on the project approach

Date	**Target**	**Topic**
June 2018	Prospective DER participants	DER contractual terms
November 2019	Contracted DER participants	Changes to DER Interface Schedule, including change from integer to float data types
April 2020	Prospective BAU aggregator participants	Aggregator design study
March 2021	DER participants	Anonymity in trial reporting
June 2021	Close down event attendees	Feedback on the project and further information required

Publications

Several publications were issued during the lifetime of the project, where learning and experience was disseminated across the industry. Table 11 presents a list of those publications. The project also issued press releases at the beginning of the collective trials in the October 2020 and at the end of the project in July 2021.

Table 11 Publication List

Publication date	Title
March 2018	Power Potential unlocking hidden potential, **Network Magazine**
June 2018	**European Energy Market conference paper** The Power Potential Project: trialling the procurement of reactive power services from distribution-connected assets

Publication date	Title
June 2019	**IEEE paper** Enhancing transmission and distribution system coordination and control in Great Britain using power services from distributed energy resources
June 2019	**CIRED Conference papers** 1. UK Power Networks Providing Power Services from Distributed Energy Resources to Transmission System Operator via a Centralised DERMS platform 2. Integration of distributed reactive power sources through Virtual Power Plant to provide voltage control to transmission network
July 2020	**Energy World (magazine of the Energy Institute)** Flexibility for the Future
August 2020	**CIGRE Conference paper** ESO/DSO coordination for reactive power services from DER in the UK's Power Potential innovation project: initial trial results
September 2021	**CIRED Conference paper (forthcoming)** Coordination trial of novel distributed energy resources management system to provide reactive power services to address transmission constraints

Project showcase 2018

The project organised a showcase event at The Siemens Crystal Building in London on 30 October 2018, with ~166 attendees registered. The agenda, slides and FAQ are available on the project website. At this stage the project was in test, so the project outlined to the attendees, the need for transformation in a changing world and the benefits that Power Potential could bring to the market in terms of reliability, decarbonisation and affordability. The exhibition also touched on the transition from DNO to DSO, enabling DER to address transmission challenges.

The keynote speaker was Louise Kingham, chief executive of the Energy Institute, on 'The Power of Diversity'. This presentation on the importance of gender diversity and the need to attract new skills for a time of unprecedented transformation in our industry, noted the gender diversity and female representation in the Power Potential project.

Close down event 2021 – final showcase

The close down event was held online on 24 June 2021, with 194 registrations and 110 attendees excluding the project team. The agenda, slides and a recording of the event are available on the project website [nationalgrideso.com]. The introduction by Julian Leslie and Barry Hatton (directors at NGESO and UK Power Networks) celebrated the completion of the project and achievement of the learning objectives in a very challenging project and circumstances.

One of the intentions of the event was intended to allow DER, supporting consultants and network licensee (ESO and DNO participants) to better understand how the licensees delivering the project hope to replicate and develop the project in BAU, and how others could do so. During the event we provided an overview of the project and its learning, and highlighted the list of published project outputs in section 13 of this document. The questions and feedback forms did not highlight any gaps to address.

Nine questions were answered during the event, and five subsequently. Questions were varied but fitted broadly within the following categories:

Future of Power Potential – this was a common theme where attendees wanted to understand the challenges, timescales and cost benefit for implementing a BAU approach. Had there been any interest from other DNOs and what would be the impact on related initiatives, such as reactive reform work and collaboration with other new initiatives/projects? This demonstrated the appetite from the industry in moving this initiative forward into BAU but it was noted that only two months after trial completion and a month after publication of the trial reports, this was probably too early to judge.

DNO/DSO Network Services – there was interest in the potential for reactive services to be deployed on the DNO network, as opposed to just the transmission system, thereby managing transient events at all system voltages. UK Power Networks is expecting to develop the capability for DER to be used for voltage control for both distribution and transmission. We also clarified that Power Potential was designed to be stackable with other flexibility services.

Technical Capability – technical questions exploring the technical limitations of Power Potential, e.g. minimum level of reactive power capability, size of battery storage and effectiveness of DER to displace transmission connected generation. We responded and referred participants to detail in the SDRC reports.

Learning dissemination and feedback – DER trial participants liaison

Customer information and feedback sessions were held continually throughout the project and during live trials. DER Weekly Progress meetings were held with each customer in the lead-up to site works and commissioning, to gauge site readiness and support requirements for commissioning and mandatory trials.

Ahead of the first mandatory technical trial, presentation sessions were held with DER to update on progress and explain the next steps. This included

- Commissioning performance updates
- Mandatory Technical Trials explanation of what to expect in terms of operational environment, data collation and analysis requirements, including examples of testing.
- Wave 1 and 2 Trials progress update
- DERMS control and interface with DER
- Opportunity for questions

Following the project's commitment to provide customers with regular feedback on DER performance and learning during the trials, a series of customer feedback sessions were held with each customer part way through the trials. The sessions highlighted technical observations made during Wave 1 technical trials and some important changes/upgrades that were implemented as a result. The sessions then focused on DER responses since the start of Wave 2 and additional technical learning going forward.

Following completion of the trials, customers were approached by the project team once again, to gain their views on their learning and experience from the project, from trials preparation through to trials delivery. The customers were generally very positive from a number of perspectives, e.g. co-ordination of the lab testing and commissioning, and detailed feedback and suggestions were included throughout SDRC 9.6.

Examples of feedback quotations include:

- 'This was a really interesting presentation on the project.'
- 'Quite easy to understand for a non ESO place'
- 'Good content, well presented'
- 'Interesting project.'
- 'Project will be instrumental in how we manage the future challenges of a power system.'
- 'Good presentations'
- 'A worthwhile exercise… great strategic opportunity …has ability to open markets which have previously been closed to assets like ours'.

13. Key Learning Documents

Below is a summary of the reports and outputs that have been produced to share learning. They can be downloaded from the NGESO project website or the UK Power Networks innovation website.

Table 12 Published reports – with hyperlinks

Document Title	Last update
SDRC Document archive	
SDRC 9.1 Technical High-Level Design	17 Oct 2017
SDRC 9.2 Commercial and Detailed Technical Design	27 Dec 2017
SDRC 9.3 Commercial Tendering Process report and finalised Trial Approach	03 Jul 2018
SDRC 9.4 Customer Readiness Report and Performance of the Technical Solution in a Controlled Environment	02 Dec 2019
SDRC 9.5 Cost Benefit Analysis	10 May 2021
SDRC 9.6 Trials Report	04 May 2021
SDRC 9.7 DSO risk-reward framework	16 May 2021
Academic reports	
Imperial College London - Market Framework for Distributed Energy Resources-based Network Services	27 Jun 2018
University of Cambridge - Reactive Power Management and Procurement Mechanisms	27 Jun 2018
Imperial College London - Evaluating Synergies and Conflicts of DER Services for Distribution and Transmission Systems and Market Power Assessment	10 May 2019
Imperial College London - Validation of the Power Potential Commercial Trials	24 Mar 2021
Technical outputs for DER participation	
Technical Characteristics Submission Spreadsheet	
Guidance on Wave 1 Mandatory Technical Trials v1.1	15 May 2020
DER Interface Schedule v2.3.2	10 Jun 2020
DER Test Specification	30 Jun 2020
DER Technical Requirements	11 Aug 2020
DER Commissioning procedure for trial	February 2020
Aggregator Design Study	April 2020
UK Power Networks Control Room Procedure for trial	
DER Technical Guidance Document	
Commercial/ contractual outputs	
DER Framework Agreement - Document Summary	13 Mar 2019
UK Power Networks – DER: Framework Agreement	10 Oct 2019
Market Procedures V7 October 2020	13 Oct 2020
Participation Payments Letter (issued after commissioning)	13 Oct 2020
Reactive Power Commercial Procedure Wave 2 and 3	29 Mar 2019
UK Power Networks – DER: Variation Agreement relating to a Connection Agreement	19 Aug 2019
Historic utilisation charts (indicating utilisation of reactive power services by NGESO)	June 2018
Early project outputs	
A Guide to Participating	June 2018
Heads of Terms – indication of future contractual terms	August 2018
June 2018 Consultation Responses on contractual terms	June 2018
Power Potential FAQ	October 2018
Useful Documents	
Summary of the Power Potential proposal	17 Oct 2017
Original NIC project submission to Ofgem	24 Oct 2017
Power Potential project team contact sheet	July 2021

Project Progress Reports

The project team also provided a detailed Project Progress Report (PPR) for Ofgem throughout the project. These reports contained enough detail for Ofgem, industry and stakeholders to evaluate the progress of the project. These reports are listed in Table 13, and were also published on the project websites.

Table 13 Power Potential published progress reports

Report Title	Date
6 monthly report June-December 2017	15 December 2017
Annual Summary Report December 2018	12 December 2018
Annual Summary Report December 2019	16 December 2019
Annual Summary Report December 2020	16 December 2020

14. Useful Information

Data Access Details

Network licensees must tell anyone who is interested how they can request network or consumption data gathered during a project. From 30 September 2017, network licensees must have a publicly available data sharing policy setting out the terms on which such data will be provided like NGESO's data sharing policy, relating to Network Innovation Allowance (NIA) and Network Innovation Comptition (NIC) projects.

Interested parties can access any network and consumption data gathered because of this project in accordance with NGESO's published policy, click here.

UK Power Networks follows a similar innovation data-sharing policy, click here.

Ofgem expects network licensees to share network and consumption data if the person requesting it can show it is in consumers' interests to do so. Data may be anonymised and/or redacted for commercial confidentiality or other sensitivity.

Contact Details

For more about the Power Potential project, please review the website or contact via the mailbox addresses listed below

Website: https://www.nationalgrideso.com/power-potential

Project Leads:

National Grid ESO: **Dr Biljana Stojkovska**

UK Power Networks: **Dr Rita Shaw**

Emails:

National Grid ESO: box.PowerPotential1@nationalgrid.com

UK Power Networks: powerpotential@ukpowernetworks.co.uk

Power Potential project team contact sheet

Accuracy Assurance Statement

This Power Potential (TDI 2.0) project completion report has been produced in agreement with the entire project steering committee. All project partners have been involved in writing and reviewing it. The report has been approved by the Power Potential project steering committee and by Julian Leslie, Head of Networks. Every effort has been made to ensure that all information in the report is true and accurate.

Signed:

Print: Julian Leslie

This report has also been peer reviewed by colleagues at Western Power Distribution and copy of the peer-review letter is in Appendix A.

Appendices

Appendix A – Letter of Assurance from Peer Review

The peer review was carried out by Western Power Distribution and confirms that the objectives and deliverables as agreed in the Project Direction have been satisfied by National Grid ESO.

WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales

Faithful Chanda,
Innovation and Low carbon Networks Engineer
Western Power Distribution
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Derbyshire
DE74 2TU

Dr Biljana Stojkovska
Project Manager – Power Potential
National Grid ESO
Faraday House, Warwick Technology Park,
Gallows Hill, Warwick
CV34 6DA

Date
08 July 2021

Dear Biljana,

RE: Power Potential Close - Down Report - DNO Peer Review

Further to your request for Western Power Distribution to review and comment on the Close Down Report produced in respect of National Grid ESO Power Potential, NIC funded project, I can confirm that we have undertaken this review and consider that the objectives and deliverables as agreed in the Project Direction have been satisfied by National Grid ESO.

In addition, subject to the requirements of the NIC funding governance, we can confirm that we consider that the Close Down Report as reviewed by Western Power Distribution is clear and understandable and contains sufficient detail and information to enable a DNO to make use of the learning generated to implement their own network solution and test similar intervention with reactive power.

Should you wish to discuss anything further or have any additional requirements that you need to address in respect of the Power Potential project, please do not hesitate to contact me.
Yours sincerely,

Faithful Chanda,

Innovation and Low Carbon Networks Engineer

Appendix B – Glossary of Terms

Term	Definition
BAU	Business as Usual
CBA	Cost Benefit Analysis
CIM	Common Information Model (IEC standard)
CUSC	Connection and Use of System Code
DER	Distributed Energy Resources
DERMS	Distributed Energy Resources Management System
DNO	Distribution Network Operator
DSO	Distribution System Operator
ENCC	Electricity Network Control Centre
ESO	Electricity System Operator
FAT	Factory Acceptance Testing
FES	Future Energy Scenarios
GSP	Grid Supply Point
Gvar	Giga-var-amperes (unit of Reactive Power)
ICCP	Inter-Control Centre Protocol
IEC	International Electrotechnical Commission
IPR	Intellectual Property Rights
MW	Megawatts (unit of active power)
Mvar	Mega-var-amperes (unit of Reactive Power)
Mvarh	Mega-var-ampere-hours
NFT	Non-Functional Testing
NGESO	National Grid Electricity System Operator
NOP	Network Operating Procedure
OAT	Operational Acceptance Testing
ORPS	Obligatory Reactive Power Service
P	Active Power
PAS	Platform for Ancillary Services
PQ	Active Power v Reactive Power, capability envelope or permitted range for a DER
PQM	Power Quality Metering
Q	Reactive Power
RDP	Regional Development Programme
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SDRC	Successful Delivery Reward Criteria
SIT	System Integration Testing
TDI	Transmission Distribution Interface (noting TDI 2.0 as the original project name)
TNUoS	Transmission Network Use of System
UAT	User Acceptance Testing
UI	User Interface
UKPN	UK Power Networks
V	Voltage
VPP	Virtual Power Plant
VQ	Terminal Voltage v Reactive Power

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nationalgrideso.com//future-energy/projects/power-potential