Annual Progress Report

The Power Potential Project

January – October 2021

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Executive Summary

This report provides a summary of progress across all project workstreams and reporting in 2021. Power Potential has delivered technical trials of automated voltage control services from DER (Distributed Energy Resources) to National Grid Electricity System Operator (ESO), enabled by UK Power Networks. This final annual report has been prepared for compliance with the annual reporting requirement in the Network Innovation Competition project governance; however the content largely reflects information already published.

The COVID-19 pandemic had a material impact on the Power Potential trials compared to as originally envisaged. In 2020, there was a pause in DER commissioning ahead of the main trial stage, and a switch to more remote delivery approaches for trials. The proposed approach agreed with the project's steering committee members (National Grid ESO and UK Power Networks) included extending the timescale of the project, without alteration of the trial structure, scope or financial commitment to DER. The trial timescale was extended to end March 2021, with reporting completed in August 2021. The timescale changes were reflected in a material change request to Ofgem in November 2020, which was approved in February 2021.

In 2020, the Mandatory Technical Trials and Wave 1 Optional Technical Trials had provided important technical and operational learning for DER, National Grid ESO, UK Power Networks and the DERMS developer (ZIV Automation). This trial experience had informed multiple amendments and improvements to the DERMS, the DER contractual limits and supporting infrastructure ready for the Wave 2 trials which ran from January 2021 to the end of March 2021 (see Table 1).

Building on learning from the 2020 trials, in 2021 we delivered the Wave 2 technical and market trials in collaboration with the four fully commissioned DER. We also delivered active power trials demonstrating simultaneous active and reactive power service delivery instructed by DERMS under ESO instruction. DER were paid for their participation in the trial waves under the settlement process developed for the project. Following the trials, formal project reporting was completed in May 2021 with an update on the previously-confidential report on cost-benefit analysis, a report on trials and transition to business-as-usual, and a report on the future DSO risk-reward framework. The online close down event was held in June 2021, followed by the publication of the project's close down report in August 2021, summarising project learning and the potential approach to replication and implementation.

In combination, we have delivered an operable and supportable system for the Wave 2 Market Trials, consistent with the service delivery timescales in the original design, and explored site-specific issues with individual DER performance.

The market element of the Wave 2 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 the Power Potential methods could be another option for National Grid ESO to manage dynamic voltage support, alongside traditional options such as STATCOM/SVC and transmission-connected generators. As part of its initial business plan for RIIO-ED2 (the next regulatory period for electricity distribution), UK Power Networks committed to develop its DSO capabilities and to work with National Grid ESO to deliver a business as usual Power Potential offering by 2028 across its South Eastern and Eastern regions, as part of Regional Development Programmes in those areas.

Table 1: Power Potential trials calendar

DER Commissioning & Wave 1 Mandatory Trials	March – November 2020: Ran first remote Mandatory Trials (MT) in June with the initial commissioned DER, develop process and DERMS for subsequent MT Once COVID-19 restrictions lifted on site work, we commissioned and ran Mandatory Trials for the rest of the DER.	
Wave 1 Technical Trials	14 October 2020 – 10 December 2020 (Three DER initially)	Eight weeks, then reconfigure system for next trial phase
Wave 2 Market Trials	6 January 2021 – 28 March 2021	12 weeks

Project Manager's Report

This year has seen the project complete system upgrades, deliver the Wave 2 live trials, close out settlements, and all subsequent reporting. Overall this has provided technical and commercial demonstration and analysis of the Power Potential method to deliver voltage control services from DER to transmission enabled by the distribution system operator and DERMS system.

As notified to Ofgem in April 2020, project delivery was significantly affected by COVID-19 restrictions, with a material impact on Power Potential trials continuing as originally envisaged. This particularly affecting site commissioning. A revised trial timescale completing in March 2021 was set out in the April 2020 letter. This was part of a material change request submitted in November 2020, which was formally accepted in February 2021.

Building on learning from Wave 1 trials in 2020, changes were made to DERMS in December 2020 ready for the Wave 2 trials to run from January to March 2021.

Project delivery was structured into five workstreams:

- Technical (WS1)
- Commercial (WS2)
- Business processes (WS3)
- Trials (WS4)
- Project management (WS0)

Progress in project delivery workstreams is described in the following sections.

1. Workstream 1: Technical

Overview of the DERMS solution

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 National Grid ESO to DER services. More specifically the DERMS enabled DER to offer:

- Dynamic reactive power services to National Grid ESO (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 National Grid ESO, 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.

The final live system architecture is shown in Figure 1 overleaf.

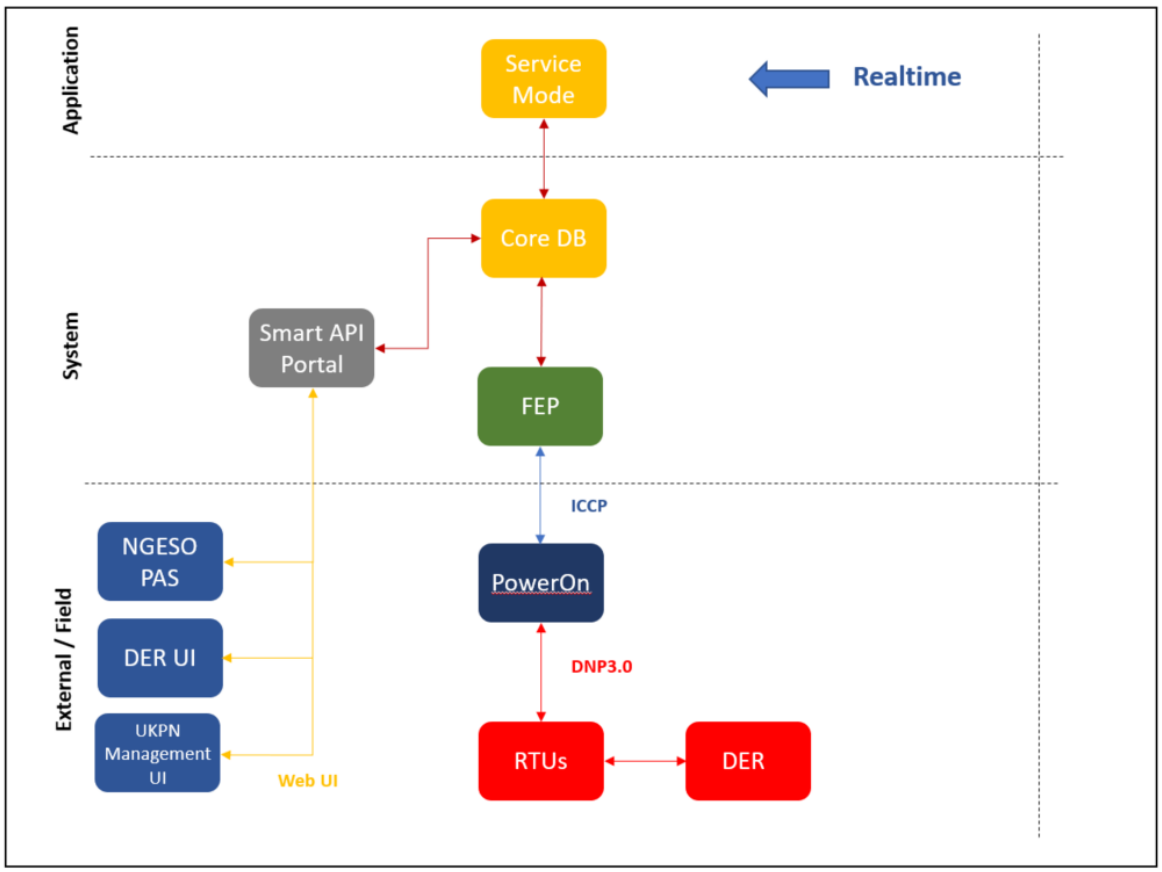


Figure 1 The final live system architecture

Core DB	DERMS core database
FEP	Front end protocol
PAS	Platform for Ancillary Services
PowerOn	UK Power Networks' network management system
RTU	Remote Terminal Unit
UI	User Interface (for DER and UK Power Networks to interface with DERMS)

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.

Technical challenges resolved

On 10 December 2020 shortly after completion of the Wave 1 trials, a DERMS upgrade was deployed on the live production environment. This was not the official start of the Wave 2 trials but DERMS was put into Wave 2 mode with 4-hour service windows in readiness for the commercial trials to January 2021.

The DERMS upgrade included the changes in integration design arising from learning from the Wave 1 trials (see section 2.1 of SDRC 9.6) involving changes to reduce data volumes, reduce service interruptions and restore the service recalculation frequency to 10 second intervals. The upgrade also resolved defects affecting active power services. All aspects all worked well after the upgrade.

At the time of the start of Wave 2 trials, there were no Priority 1 defects. However, a daily manual workaround was required by the UK Power Networks team to reject DER availability in the case that there was 'no nomination' advised by National Grid ESO's commercial team as having been entered into the PAS system. The default 'accept' behaviour had been suitable for test and for Wave 1 trials but was incorrect for Wave 2.

Resolution of that issue and all other known defects including cosmetic improvements to the DERMS Web Interface were triaged for the last planned upgrade of DERMS in February 2021. The initial weeks of Wave 2 also featured multiple service interruptions due to loss of PAS-DERMS connectivity (see section 2.3.3 of SDRC 9.6), with the service needing to be manually re-enabled by the UK Power Networks support team. The February 2021 upgrade also made DERMS less sensitive to these connectivity losses, and this was the version of DERMS delivering the final six weeks of the Power Potential Wave 2 trials.

Technical challenges identified for future resolution

The February upgrade required extensive testing pre-deployment by UK Power Networks and ZI Automation due to functional dashboard issues arising from data model duplication within the DERMS MongoDB database. Furthermore, in the final weeks of the trials, DERMS developed a database conflict on one of the Grid Supply Points when inputs from simultaneous inputs from PowerOn and PAS caused a processing conflict. A resolution was identified by ZIV Automation but could not be tested and deployed before the end of the trial. These issues highlighted the importance of database integrity testing in additional to functional testing of DERMS, and potential failure modes to address and test in advance of a BAU solution.

A key functional area of improvement for BAU would be to implement dynamic response proportional to the scale of available DER reactive response. The DERMS system and its integration with PAS was designed and tested with a fixed 'Qbase' of 100 Mvar, much larger than the contracted DER resource in the trials. This meant that for small changes in the voltage requested at the Grid Supply Point, a relatively large response from the DER would be delivered.

The design was suited to delivery of a large steady-state response. However for the future, National Grid ESO would seek a smaller dynamic response relative to the difference between the actual GSP voltage and the GSP target voltage, with the larger response reserved for the largest voltage differences i.e. more response held in reserve for post-fault conditions and lower utilisation of the service. Investigation with ZIV Automation determined that this would be achievable in future with a change in how the 'Qbase' is set in DERMS to be based on the contracted resource, and also that the DERMS controller could be adjusted from integral to proportional response. Further information on this aspect of the project leaning can be found in section 2.4.2 of SDRC 9.6.

End of trials – decommissioning and preparation for BAU

As set out in the Close Down Report, a number of changes to the PAS and DERMS systems would be desired prior to implementation as a BAU service. As such the PAS and DERMS systems for trial were decommissioned at the end of the project, including the DERMS-PowerOn-RTU-DER

integration and control. However the project provides a template for how such systems could be reintroduced in future with the desired changes.

2. Workstream 2: Commercial

The commercial workstream was responsible for the design and development of a route to market for DER to deliver reactive power and active power services to National Grid ESO. Having developed the contractual arrangements in previous years, 2021 focused on the commercial implementation in the DERMS Wave 2 solution including National Grid ESO's procurement decisions and capturing the learning from the customer experience through the project.

The commercial team moved its focus towards continued engagement with participants during the trial through responding to all commercial queries; weekly market reporting; regular newsletter updates to the wider stakeholders; supporting the nomination process and technical workstreams where appropriate; supervising the settlement process and capturing and providing analysis for the various SDRC reports during this reporting period.

Regional Market Advisory Panel (RMAP) Updates

The project team continues to host quarterly RMAP meetings and publishes the minutes on the project website.

- Quarter 1 – 6 January 2021
- Quarter 2 – 18 May 2021

At the 6 January 2021 RMAP meeting, we presented the Wave 1 optional trial results, plus a summary of Wave 2 commercial trial approach and market reporting.

At the 18 May 2021 RMAP meeting, there was a presentation of final trial results and a feedback session from DER on trials and the overall project.

End-to-end collective 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 National Grid ESO 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 National Grid ESO assessments team to review.
- At 14:00 National Grid ESO 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 National Grid ESO 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.

Recruitment and continued engagement

The recruitment process for trial participants closed prior to the start of the wave 1 trial. However, engagement with existing and any potential future participants in the provision of reactive services continued to ensure they were kept up to date with the project progress and outcome. This involved conducting one to one sessions with interested parties when requested as well as regularly updated our mailing lists to ensure parties were kept informed.

The engagement process was led jointly by UK Power Networks and National Grid ESO.

Academia: Imperial College validation work

Engagement with the academic partners from Imperial College London progressed and the final report "Validation of the Power Potential Commercial trials" was completed. This was the final task to be completed from Imperial College's scoped work, to review the DERMS commercial calculations during Wave 2. An initial meeting was held in March 2020 between UK Power Networks, National Grid ESO, Imperial College and ZIV Automation representatives to define the case studies to be analysed in this report. Imperial College produced a document to capture the objectives and scope of the work, both at day-ahead and real-time timescales, and data input needed for the different case scenarios. Imperial College was also in contact with ZIV Automation to get the initial network data and other DERMS values needed for the analysis. The final report was published March 2021, Validation of the Power Potential Commercial Trials.

At the heart of the Power Potential project is the DERMS. DERMS computes the available aggregated DER capacity for active and reactive power (PQ curve) that can be used by the ESO at the Grid Supply Point (GSP), taking into consideration distribution network local network constraints, which is the fundamental concept of VPP. The distribution network constraints needed to be secured first before the remaining available DER capacity could be offered to the ESO as transmission services. Using this bottom-up incremental approach, National Grid ESO's use of DER via DERMS did not violate distribution constraints in the Power Potential area.

In order to validate DERMS calculation and identify potential improvements, the work described in Imperial College report aimed to:

- Review the cost curve construction logic for the day-ahead time frame based on the planned system conditions and predicted demand and DER availability. This involved checking that the DER ranking is correct and that the minimum cost solution is offered while respecting the various constraints (including the network, processing environment and time available). The nomination decision (which available band is selected) is an internal process that not expected to be reviewed.

- Investigate the impact of network losses on the VPP PQ operating curve
- Analyse the impact of different network and operating conditions affect the cost curve construction (day-ahead snapshot)

Based on the results of a spectrum of studies performed and the analyses, it was concluded that the VPP reactive power capability calculated by DERMS is aligned with the results of the Imperial College model.

DSO risk-reward framework

The SDRC 9.7 report described the commercial framework used for the Power Potential project, and provides recommendations for an enduring incentive framework for the Distribution System Operator (DSO) for wider system services such as those trialled in Power Potential.

The Power Potential project has successfully demonstrated a world-first regional reactive power market using a DERMS to resolve transmission constraints. This automated technical solution enabled day-ahead procurement of reactive power services from DER through the coordination of UK Power Networks. The trials and potential developments for a BAU transition are covered in SDRC 9.6 "Trials Report".

The trial adopted a simple commercial framework and back-to-back contractual mechanism with pass-through of service payments from National Grid ESO to UK Power Networks, and then from UK Power Networks to DER. With this approach, the project team implemented and tested the dispatch logic for the service with minimum risk exposure for the project partners and the participating DER, while achieving the technical learning and the price discovery from DER.

National Grid ESO's reactive power requirements are currently met through a combination of balancing services and network asset investment. Network assets for reactive power have been very cost effective against market options so far. However increasing operational and cost challenges to manage the system highlight that there is a system need to be addressed.

Therefore, National Grid ESO has increased the utilisation of balancing services to fill the gap when network assets are not available and/or when system requirements are higher. During these times, when there is not enough reactive capability on the system to manage voltage levels, National Grid ESO may dispatch out of merit order synchronous generation via trades or the balancing mechanism to manage the locational nature of voltage constraints.

A DSO can help resolve these needs, with the appropriate incentives in place. Power Potential can provide a more economic and efficient way to access reactive capability via a coordinated procurement and dispatch method between UK Power Networks and National Grid ESO, while respecting constraints in the distribution network.

The project has shown in SDRC 9.5 report "Cost Benefit Analysis" that there are potential savings to consumers if DER are able to deliver voltage constraint management services for the transmission network for consumers compared to building additional network assets. Additional benefits also include unlocking extra network capacity and potential cost savings for consumers from greater competition with existing market providers. These Power Potential savings result from DER market behaviour and increased effectiveness to resolve locational issues compared to other market options available to National Grid ESO.

In order to achieve this, UK Power Networks needs to ensure that its distribution network is available and agile, so that DER are able to deliver system services without facing any network constraints. As a neutral market facilitator, UK Power Networks will continue leading the way in developing local DSO flexibility markets, while developing capabilities that allow for mitigation of conflicts of services and whole system coordination. For example, service co-optimisation with National Grid ESO through the south-coast Regional Development Programme (RDP), and coordinating the dispatch of DSO ancillary services to resolve distribution and transmission constraints simultaneously.

UK Power Networks will explore enhancements to service delivery. Hence, it is crucial that the appropriate incentive framework is in place to drive performance that expands the coordination of DER services by the DSO. This coordination role will require UK Power Networks to:

- facilitate the participation of more DER as evidenced by the exponential growth of local DSO flexibility markets
- facilitate DER to compete with existing market providers to National Grid ESO, to enable potential cost savings
- resolve technical and economic complexities by optimising the dispatch of DER and mitigating service conflicts
- ensure that the distribution network will continue to be operated safely and reliably with no additional costs due to uncoordinated dispatch of system services.

SDRC 9.7 describes options for an enduring incentive framework for the DSO, from cost pass-through to enhanced whole system coordination with a DSO performance incentive.

Under the pass-through option, the DSO recovers costs related to operating and maintaining DERMS. However, it does not take any corrective or optimisation actions outside the nominations from National Grid ESO to mitigate for reduced service delivery, as it is only incentivised to increase DERMS availability and DER participation. This should be considered the minimum level of coordination between UK Power Networks and National Grid ESO to enable the provision of whole system services.

Under the second option, UK Power Networks and National Grid ESO continue to collaborate with increased exchange of data and network modelling information. UK Power Networks optimises DER dispatch in a cost-efficient way, while reconfiguring its network and using active network management measures. The above along with additional DER participation facilitated by the DSO can lead to reduced delivery risk and costs for National Grid ESO. Hence, the DSO needs to recover the costs for these additional actions and system development, while being appropriately incentivised to enhance delivery of service through a dedicated DSO performance incentive. This enhanced whole system coordination creates an energy system fit for the future that helps the transition to Net Zero. This option could be incentivised in the future as an identified activity with suitable performance metrics as part of the RIIO-ED2 DSO Output Delivery Incentive (ODI) framework.

Further variations between and around these options are being explored by the project partners.

This report on the DSO risk-reward framework is complemented by SDRC 9.5 (Cost Benefit Analysis) and SDRC 9.6 (Trials Report). These other SDRCs further explore the potential benefits, key learnings from the trials and considerations of transitioning to BAU.

3. Workstream 3: Business processes

National Grid ESO

Preparations for the trials have continued with business processes finalised for the key elements of National Grid ESO's operation during service delivery. The trial design developed by the commercial workstream and trials delivery workstream identified a series of trial waves, each of which will necessitate different business processes and work instructions to be developed and agreed with training for the affected business functions. Business processes were confirmed for the different areas summarised in Table 2 and detailed work instructions/standard operating procedures prepared for each wave of trials.

Table 2: National Grid ESO Process changes adopted for the Power Potential trials

National Grid ESO Process changes implemented for the Power Potential trials		
Theme	**Purpose**	**Description**
Network data (IEMS)	To ensure DERMS receives 400kV measurements	• Control System Support is in place and ICCP connection validated.
Dispatch (Wave 1 and Wave 2)	To define Control Room responsibilities during Wave 1 and Wave 2	• Business procedure established and utilised for the Wave 1 reactive power trials. • Business procedure for Wave 2 finalised for use during the trial. • Weekly advice/guidance produced for control room personnel for Wave 1 trials is in place [1] • Defined and agreed timings for active power trials
Nomination (Wave 2)	To establish the approach to nominate the service required in response to the system need	Assessment logic for Wave 2 according to Target Average Cost (TAC) completed and shared with RMAP. Assessment process has been established and tested. Commercial procedure for Structuring and Optimisation for daily nomination process during Wave 2 enacted. To include processes and resources for conducting the nomination on the weekends
PAS (Wave 1 and Wave 2)	To ensure visibility and dispatch of the Power Potential reactive power service	• Further PAS-DERMS testing in advance of Wave 2 to mitigate any issues with the new data exchange requirements.
Settlements (Wave 1 and Wave 2)	To establish how payments for services delivered will be reconciled with the service accepted by National Grid ESO and the service delivered.	• Settlement process and service agreed and implemented.

UK Power Networks

Previous annual reports have outlined the processes developed for signing customers up to the service, commissioning, the setup of 'hypercare' for support during trials and processes for settlement, including the 'self-bill' approach defined by the project. This allows the project to pay participating DER based on their service delivery according to the trial contract, without requiring the DER to submit invoices.

There were three key areas of business process activity in 2021.

1. Settlement was implemented for the Wave 2 commercial trials and active power trials. Relative to the Wave 1 Technical Trials payments based on available hours only, this was a more complex process based on accepted price and delivered outputs.
2. End-of-trials decommissioning – managing the end of service support agreements, and decommissioning of systems at the end of trials, so that no services could be instructed after expiry of the trial contractual agreements.

[1] During Wave 1, National Grid ESO define the PAS instructions for the current week, based on the outcomes of the previous week e.g. adjusting parameters to facilitate achieving more reactive power absorption overnight

3. High-level review of future service requirements for BAU implementation – across business process, service design and DERMS functionality development. This was internal business preparation to support how Power Potential can be developed in future into a BAU service.

Settlement

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 PI data historian. Whilst the data in-feed from PI had been established, issues were encountered with the DERMS to BI data transition.

ZIV had resolved an integration issue with sending settlement data from DERMS to UK Power Networks' BI system ahead of the Wave 2 trials, but the project team queried the validity of values in the report. ZIV advised in January 2021 that they were not able to fully fix the component of DERMS which extracts settlement data (DER prices, DER availabilities, PAS nominations and PAS instructions) to BI in time for preparation of the first Wave 2 settlement statement. Therefore, the fully automated settlement process was unable to function properly as expected.

PAS instructions such as GSP voltage set points could be extracted from DERMS, but the project team developed workarounds to extract the remaining DERMS data manually daily. This was assembled in the expected format and sent to the BI system for processing with the metering data from UK Power Networks' PI data historian.

When the first Wave 2 settlement statement was created in February 2021, an issue was identified with combining the minute-by-minute settlement metering data from PI (reported on change rather than every minute) with the price data by half-hourly settlement period. This had not been identified earlier due to the initial focus on extracting price data from DERMS rather than creating an equivalent DERMS input. This challenge was resolved before the next month's statement, and DER were paid in full but with a delay on their initial utilisation payment. However this feature of the reporting of metering data on change will need to be considered in a BAU settlement system.

The automated process design would need to be finalised, tested and implemented for BAU, reflecting the revised commercial and contractual framework for the BAU service.

4. Workstream 4: Trials Delivery

Table 3 shows the Power Potential trial schedule. In 2021, the Wave 2 Trials were delivered which was the final trial stage.

Table 3: Power Potential trial schedule with 2021 component shaded

DER Commissioning & Wave 1 Mandatory Trials	March – November 2020: Ran first remote Mandatory Trials (MT) in June with the initial commissioned DER, develop process and DERMS for subsequent MT Once COVID-19 restrictions lifted on site work, we commissioned and ran Mandatory Trials for the rest of the DER.	
Wave 1 Technical Trials	14 October 2020 – 10 December 2020 (Three DER initially)	Eight weeks, then reconfigure system for next trial phase
Wave 2 Market Trials	6 January 2021 – 28 March 2021	12 weeks

Available market hours for the Wave 2 reactive power trials were for full trading days starting at 23:00 (11pm). Active power trials ran in specific service windows during Wave 2.

Wave 2 commercial trials

The purpose and structure of the Wave 2 trials were described earlier in the Workstream 2 section. Wave 2 of the trial was designed to support "price discovery" from DER that were able to bid on both availability and utilisation price in a competitive environment, amongst themselves, within the confines of the trial budget. DER were able to reflect any risk or cost associated with the provision of the service in the most efficient way they chose.

DER resource procured during Wave 2 was not considered as contributing to securing the reactive power requirement for the system as per other balancing services but was essentially surplus to test the price discovery principle, given the unproven nature of the service.

Payments to DER came from the project budget, so it was important to develop a process to monitor the budget allowance as well as create price discovery.

Power Potential Wave 2 trials commenced in January 2021, with participants submitting their service availability on 5 January for the first service start deliver on 6 January 11:00am.

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 National Grid ESO, which in turn made a procurement decision based on volume available and accounting for the overall and daily trial budget. This decision was entered in PAS which communicated to DERMS; the DERMS then indicated to each DER by 5pm day ahead whether it was accepted for service as part of its 'production schedule' responses.

A procured DER from a VPP 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).

Wave 2 trial results

The Wave 2 market operated for a total of 1,772 hours this was slightly less than the original objective of the project, to run the market for a minimum of 1,800 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 as outlined in section 2.5 of SDRC 9.6). Throughout the trial there were different bidding strategies across the various GSPs. These are displayed in SDRC 9.6 showing the availability and utilisation prices accepted at each GSP/VPP across the Wave 2 trial.

Active power trials

Active power trials were conducted during the Wave 2 trials at the Bolney and Ninfield GSPs on Saturday 6 March 2021 and Friday 19 March 2021 respectively.

The objective of these trials was to demonstrate the technical capability of DER and DERMS to provide an active power response via DERMS instruction and also to test both active and reactive power instructions simultaneously. With reference to the Power Potential Market Procedure, after receiving an instruction, the DER unit would need to be capable of responding by automatically

ramping the active power generated up and/or down according to the DERMS instruction and within the plant limitations indicated by the Minimum and Maximum Active Power Parameter's submitted.

The active power instructions were for a limited time (approximately five minutes each), i.e. the instruction was sent to the DER and once the required MW was achieved (taking into account plant ramp rates), the instruction was held on for five minutes. The MW instruction was issued as a MW set point and calculated relative to the submitted EOL. The contract noted that DER needed to meet the MW set point within two minutes of receiving the instruction.

As there were only two DER that took part in the active power trial, it was difficult to draw wide-ranging conclusions, though the tests showed that DER successfully delivered active power and the simultaneous delivery of active and reactive power is achievable within the technical framework outlined for the project.

The tests showed that delivering both reactive and active power at the same time is more challenging, and the configuration of the DER controller, DER P-Q limits and any interaction with the DERMS is important.

Additional learning was also captured in terms of how DERMS sends active power instructions in terms of a difference in MW compared to the EOL rather than to a specific MW value. This was shown to be challenging if the actual output of the generator is different to the EOL and will need to be considered in any future design. For testing purposes, using this methodology has proven the concept on a technical level, though further review would be required to determine the consequences of how DERMS instructs active power in this way across multiple DER/GSPs (i.e. how MW shortfalls or over estimation would be catered for) and updates EOL declarations due to system faults.

During the trials two DER were participating in both the Firm Frequency response (FFR) and Enhanced Frequency Response (EFR) markets with no significant conflicts, but "under delivery" of service in some circumstances. It is envisaged that DER would continue to be technically capable of delivering active balancing services alongside Power Potential based on the results of the simultaneous active and reactive power testing.

Further information in the results for the active power trials can be found in section 2.6 of SDRC 9.6.

Wave 3 commercial trials

The concept of the Wave 3 trials was to utilise participating DER to secure the system reactive power requirement. DER would submit availability and utilisation prices (as during Wave 2), and these prices would be compared against alternative actions available to National Grid ESO (including 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 be made directly from the ESO'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 meant that Wave 3 could did not go ahead. This ensured that the project retained its focus on the key objectives of the original bid which could be delivered through the Wave 1 (technical) and Wave 2 (commercial) trials.

5. Business Case Update

The business case was updated and published in 2021 in 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 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.

Replication and Implementation

Further information on replication and future implementation of the Power Potential method is provided in sections 10 and 11 of the Close Down Report. 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 its DSO capabilities and to work with National Grid ESO to deliver a business as usual Power Potential offering by 2028 across its South Eastern and Eastern regions, as part of Regional Development Programmes in those areas.

6. Project Against Plan

A material change request letter was submitted to Ofgem on 9 November 2020, requesting access to the project contingency, changing the project end-date to 31 December 2021, and setting out the timing of the remaining Successful Delivery Rewards Criteria (SDRC) reports. These had been revised to reflect the updated project delivery plan and the revised delivery dates are summarised in Table 5 below, notified to Ofgem in April 2020 and contained in the 9 November 2020 material change request sent to Ofgem, which was approved in February 2021.

7. Successful Delivery Reward Criteria

The three final SDRC reports were delivered in 2021, consistent with the agreed dates in the change request.

Table 4: Revised schedule for the 2021 SDRC reports

	SDRC 9.5	SDRC 9.6	SDRC 9.7
Title	Cost Benefit Analysis	Trial Phase Report	DSO risk-reward framework for providing wider system services
Original submission date	31 December 2018	31 December 2019	31 December 2019
Revised submission date	31 March 2019 (confidential) 7 May 2021 (public)	30 April 2021	15 May 2021

Table 5: Status of the project's 2021 Successful Delivery Reward Criteria (SDRC)

SDRC	Progress
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 10 May 2021.
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 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**	Completed and published on 16 May 2021 Read here

- **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**

8. Data Access Details

Interested parties can access any network and consumption data gathered because of this project in accordance with National Grid ESO's published policy. UK Power Networks follows a similar innovation data-sharing policy.

9. Learning outcomes

Dissemination activity from the Power Potential project has continued throughout this reporting period to keep raising awareness and the profile of the project and encourage trial participation with key stakeholders and audiences within the industry. Engagement with DER and aggregators has been critical to successful delivery of the projects' trials and overall project objectives.

The projects' engagement strategy continues to communicate the key benefits that the Power Potential service will bring, including:

- making a material contribution to voltage control and constraint management on the National Electricity Transmission System
- providing an additional revenue opportunity for DER
- gathering evidence on the level consumer savings that could be achieved through adoption of the Power potential approach following the trials.

The engagement process is led jointly by UK Power Networks and National Grid ESO. Both parties have continued to utilise existing relationships with providers within the trial region, through the Business Development and Contracts and Settlements team within National Grid ESO. The key channels used in this reporting period are listed below in External Engagement.

Project website

Maintaining a good website is one of the best ways to promote an activity. To ensure the project is connecting with its stakeholders, the project website has been updated regularly. On the project website, users can learn about the project at a high level or find more technical detail using the sign posted tabs, such as finding out about requirements for participation in the project or learning about the DERMS platform. The website hosts all the relevant documents the DER need to learn about participation requirements, or complete to take part. To make the site user friendly and help navigation, the website now includes signposted document folders. A direct link has been added to the website which means users can request to join the mailing list.

The project website includes an 'events and news' section, which allows stakeholders to follow the project's external engagement activities. A dedicated email address (box.PowerPotential1@nationalgrid.com) appears at the top of the page, allowing for further questions or queries to be submitted directly to the team.

The project team has tracked the number of visitors to the website.

Table 6: Website analytics for period 1 January – 31 July 2021 for the project webpage

Page Hits	**2,519**
Visitors	**2,102**
Downloads	**769**
Average time on page	**5 minutes 09 seconds**

In 2021, UK Power Networks created a parallel page for key project outputs, linking to the more comprehensive joint project page on the National Grid ESO website.

External engagement

Close down event

The final showcase or close down event was held online on 24 June 2021, with 194 registrations and 110 attendees excluding the project team. The introduction by Julian Leslie and Barry Hatton (directors at National Grid ESO and UK Power Networks) celebrated the completion of the project and achievement of the learning objectives in a very challenging project and circumstances.

The project team had analysed and compiled the trials' technical performance, commercial results, key insights and next steps for the project. The event featured speakers from both National Grid ESO and UK Power Networks and an extended Q&A so the audience could put questions to our experts. The presentation and a video recording of the event can be found on the project website.

Nine questions were answered during the event, and five subsequently. Questions were varied but fitted broadly within the following categories: future of Power Potential, DSO/DNO network services and technical capabilities.

Publications

The National Grid ESO and UK Power Networks press release at the end of the trial was picked up in many trade publications and on LinkedIn.

21 June 2021 **UK Power Networks - World-first trial paves the way for new renewable energy market**

Conference publications

One conference publications was prepared for the project during this period, for the CIRED conference in September 2021. The title was "Coordination trial of novel distributed energy resources management system to provide reactive power services to address transmission constraints".

Newsletter to project stakeholders

At the end of 2019, the project issued the first newsletter update to the main project stakeholders. This has been established as regular project communication occurring every two weeks, to update DER and other RMAP participants on the projects latest progress. These continued in 2021, fortnightly through trials and then after trials as project outputs were produced. The final newsletter was issued in August 2021, highlighting the project close down report

Social media

Where the project has enjoyed any significant progress, these have been shared internally and externally (Figure 2) to enhance the profile of the project. Posts below linked to the 'Power Potential Final Showcase Event' on 24 June 2021 and the end of the project.

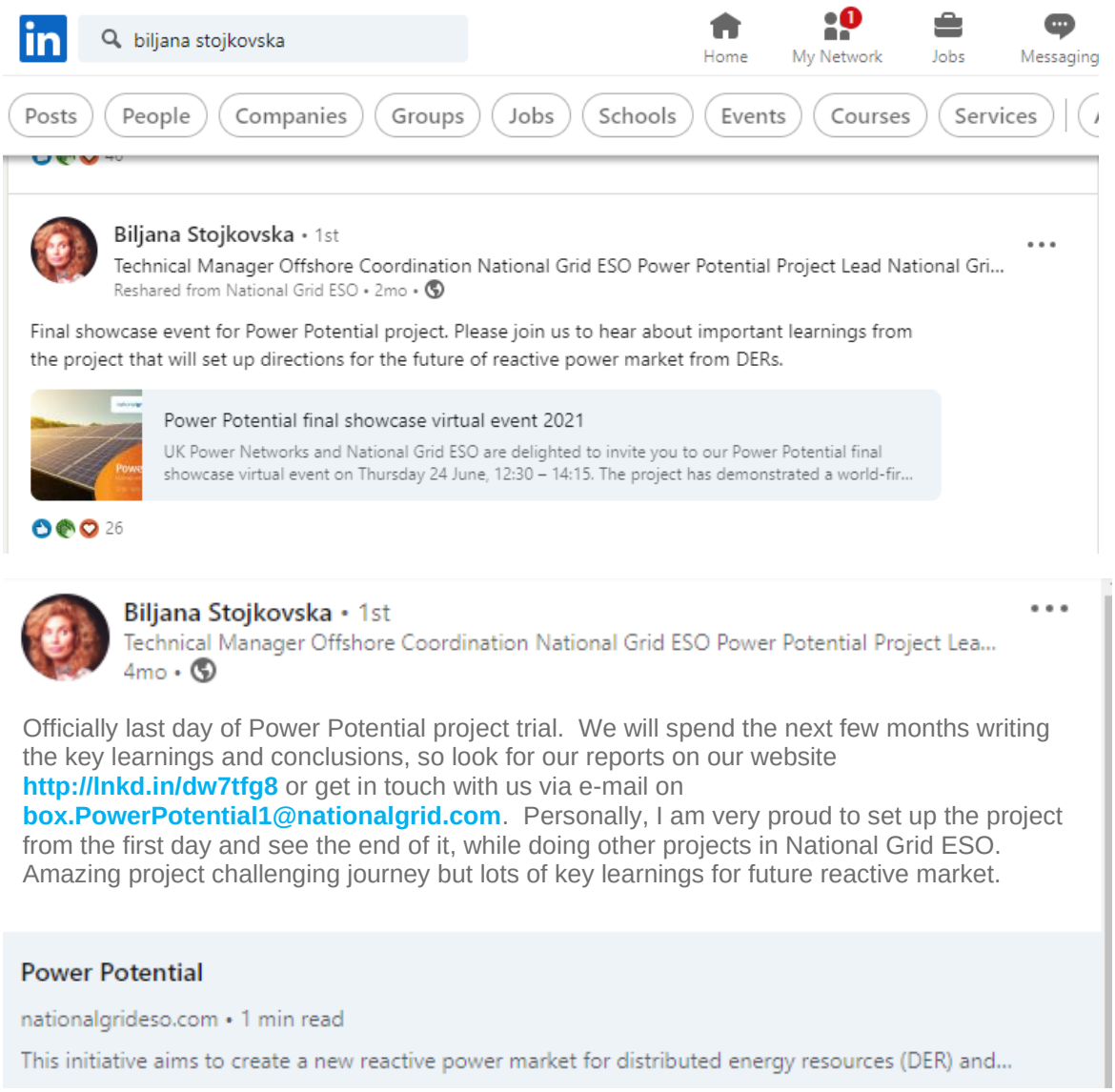


Figure 2: LinkedIn visibility of End of Project

10. Intellectual Property Rights (IPR)

The project recognised 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[2] 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 and the Foreground IPR is summarised in Table . Many of these documents are already publicly available in the key learning documents as listed in section 13 of the closedown report. 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 10 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	National Grid ESO and UK Power Networks
Project	Project Handbook	National Grid ESO and UK Power Networks
WS1/2	Use cases definition	National Grid ESO and UK Power Networks
WS2	Communication and DER Engagement Plan	National Grid ESO and UK Power Networks
WS1/2/3	SDRC 9.1 Detailed design	National Grid ESO and UK Power Networks
WS1/2	Functional and non-functional requirements for TDI 2.0 technology solution	National Grid ESO and UK Power Networks
WS1/2/3	SDRC 9.2 Detailed design	National Grid ESO and UK Power Networks
WS1/2/3	SDRC 9.3 Commercial Tendering Process Report and Finalised Trials Approach	National Grid ESO and UK Power Networks
WS1	Detailed Design for the DERMS Solution	ZIV Automation, UK Power Networks and National Grid ESO
WS1	Supplementary Detailed Design for the DERMS solution	ZIV Automation, UK Power Networks and National Grid ESO
WS1	Logical Architecture Design, Physical Architecture Design	UK Power Networks
WS1/2	SDRC 9.5 Cost Benefit Analysis Report	National Grid ESO, UK Power Networks and Cambridge University
WS1	Power Potential Test Strategy	UK Power Networks

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

WS1/2/3	SDRC 9.4 Customer Readiness Report and Performance of the Technical Solution in a Controlled Environment	National Grid ESO and UK Power Networks
WS4	Mandatory Trials guideline document	National Grid ESO and UK Power Networks
WS4	Optional Trials guideline document	National Grid ESO and UK Power Networks
WS4	Mandatory Trials test specifications, procedures and guidance	National Grid ESO 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	National Grid ESO and UK Power Networks
WS2/3	SDRC 9.7 – DSO risk-reward framework for providing wider system services	National Grid ESO and UK Power Networks

11. Risk Management

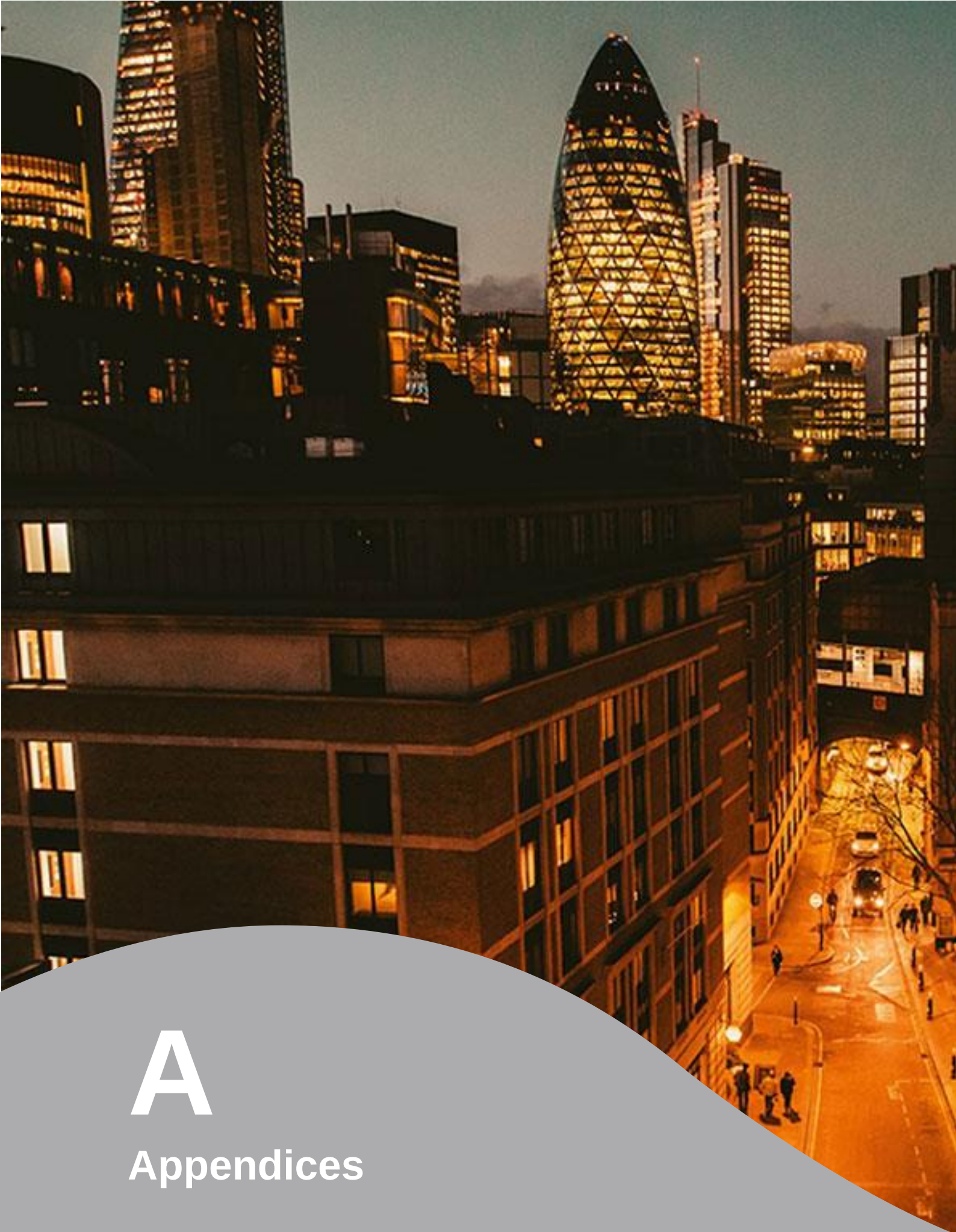
A robust project structure and governance process means that any potential issues or changes that could affect project delivery are identified quickly and actions are put in place to resolve them. The risk register is attached as Appendix 2.

12. Accuracy Assurance Statement

This progress report has been produced in agreement with the entire project hierarchy. The report has been written and reviewed by all project partners. The report has been approved by **Julian Leslie, Head of Networks at National Grid ESO**. Every effort has been made to ensure all information in the report is true and accurate.

Signed:

Print: Julian Leslie



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Appendices

Appendix 1: Project Costs Against Budget

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 11. 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. 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 11.

Table 7 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 12 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 8 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 National Grid ESO, which the project Steering Committee approved from the project's contingency budget.

Variance to the revised budget: National Grid ESO's final IT costs for integration of the project's technology solution with National Grid ESO'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 National Grid ESO 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:

- National Grid ESO IT time for integrating the project's technology solution with National Grid ESO's Platform for Ancillary Services
- National Grid ESO 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.

Appendix 2: Risk Register

Two risk tables are presented below:

Table 9: Final status of risks identified in the original bid submission
Table 10: Additional risks identified and managed since bid submission

Table 9: Final status of risks identified in the original bid submission

Risk #	Area/theme	Risk & Impact description	Mitigation/Update	Status
1	General	Final funding not awarded.	Funding secured.	Closed
2	General	Significant changes to South East Coast network make the TDi2.0 solution no longer suitable.	Future developments and scenarios considered and the solution continues to be relevant.	Closed
3		Number not used.		
4	General	Insufficient resources allocated to the project.	Project plan developed and actively managed. Partners committed to resourcing delivery of key project milestones. Contingency fund overseen by Steering Committee.	Closed
5	General	Loss of key staff delays delivery.	Ensure project handbook and file sharing systems are in place and ongoing engagement with team managers across both partners.	Closed
6	Technical	Technical limitation of ICCP interoperability between National Grid ESO and UK Power Networks cannot deliver required data transfer causing delay.	Detailed analysis undertaken of options and Steering Committee has closed this risk, agreeing use of web services.	Closed
7	Technical	Specification of the technical solution is insufficient to deliver requirements.	Specification developed with subject matter experts from across both project partners to ensure that it is fit for purpose.	Closed
8	Technical	Control system fails to perform leading to unsatisfactory trial results.	Control system to be subject to performance testing using benchmarking or simulations under various operating conditions.	Closed
9	Technical	Interoperability issues may delay response and reduce ability to control the system.	Agreed common standards for components and interface protocols.	Closed
10	Commercial	Risk that five DER/40 Mvar volume will not be recruited and commissioned in time for the trials	Ongoing engagement has enhanced the commercial proposition and increased the value of the payments to DER budget for the trials.	Closed
11	Commercial	Volume and price risk associated with each DER's sensitivity to transmission constraint it is being asked to alleviate.	Payments to DER fund in place and value increased to bolster commercial proposition.	Closed

Table 10: Additional risks identified and managed since bid submission

Risk #	Area/theme	Risk & Impact description	Mitigation/Update	Status
12	General	Ways of working at each partner creating silos.	Progress made to develop productive way of working across partners.	Closed
13	General	Project is disjointed.	Project handbook developed, weekly cross-partner workstream meetings and monthly steering committees established.	Closed
14	Finance	Budget not agreed between partners.	Budget split between partners agreed.	Closed
15	Technical	CIM integration takes longer, delaying project	Revised project delivery plan agreed with interim approach to reduce delays to trials.	Closed
16	Commercial	Delay in producing detailed workstream plan risk project delay.	Detailed project plan in place with dependencies mapped to other workstreams.	Closed
17	Technical	Risk that SDRC9.1 scope definition is compromised and not delivered in full.	SDRC9.1 delivered on time and to scope/quality.	Closed
18	Technical	CIM Export too costly or cannot be delivered.	Budget for costs has been agreed. Delivery plan rescheduled to allow more time for CIM Export delivery without delaying trials.	Closed
19	Technical	SDRC9.1 not delivered on time as regulatory and business review takes longer than anticipated.	Parallel reviews with National Grid ESO and UK Power Networks' management/regulatory teams. Delivered on time and to scope/quality.	Closed
20	Commercial	The project does not have a joint communication plan for the projects participants.	National Grid ESO and UK Power Networks carrying out joint engagement and weekly meetings ensure good co-ordination. Communications and engagement plan produced, and the plan has been approved by National Grid ESO's and UK Power Networks' communication teams.	Closed

Risk #	Area/theme	Risk & Impact description	Mitigation/Update	Status
20a	Commercial	Risk that aggregators see UK Power Networks as a competitor	Engagement with DER to clarify roles and responsibilities of partners, including through published documentation. Ongoing consideration of this risk to progress though discussion on migration to business as usual for the SDRC9.6 report.	Closed
21	Commercial	Risk of rushed procurement before agreement of proposed solution.	Technical solution requirements and design completed before publication of the Framework Agreement and Market Procedures documents for DER to participate in the trials. Procurement of service is now planned for day ahead, rather than a year in advance, therefore agreed to close this risk.	Closed
22	Commercial	Resourcing delivery of TDI 2.0 and RDP projects at same time.	Resourcing between the two initiatives has been resolved.	Closed
23	Commercial	Misalignment of TDI 2.0 and RDP deliverables.	Liaison between the two initiatives is well established. Technical, commercial and PMO linkages in place.	Closed
24	Commercial	Provision of services by DER to National Grid via UK Power Networks is insufficient to measure impact at GSP	40 Mvar combined volume of DER participating in the trials has been set as a goal by the Steering Committee, to ensure sufficient volume to measure impact.	Closed
25	Commercial	Insufficient recruitment of DER for the project trials.	DER recruitment on going, with positive response to published Framework Agreement and Market Procedure.	Closed
26	Technical	There is a risk that analogue values polled from RTUs may reflect inaccurate values.	UK Power Networks analysis undertaken of bad data and engagement with Asset Management team to agree a way forward. Action to refresh the PowerOn system with correct lines data from planning tool underway. Ongoing risk to keep under review.	Closed
27	Technical	There is a risk that tap changer control in both SGTs and Grid (distribution) transformers is not adequate for the project.	Evidence within available information demonstrates that this is not critical for minimum viable product but will be considered for next stage.	Closed
28	Technical	There is a risk that the time delay in measurements of parameters of the 400kV system to the DERMS is too long.	Data transfer via ICCP links National Grid ESO-PowerOn-DERMS on pre-production and live system indicated data transfer in around 1ms, plus 1s buffer	Closed

Risk #	Area/theme	Risk & Impact description	Mitigation/Update	Status
29	Technical	There is a risk that the time delay in an instruction sent to the DER from DERMS is too long (more than 10 seconds).	Remains under review in live trials – communications latency latency <10s, but live system temporarily slowed from 10s to 20min instruction interval due to data traffic intervals. Deadband applied to DERMS voltage setpoint to enable instruction interval to be reduced	Closed
30	Technical	There is a risk that the intensity and duration of WS1 activity needs more National Grid ESO SME input than budgeted for	January 2019 – Steering Committee approved additional resource from contingency budget to cover National Grid ESO costs.	Closed
31	Commercial	There is a risk that the commercial proposition is not compelling enough to persuade DER and Aggregators to participate in the project.	Risk closed as adequately covered by Risk 9 Webinar held 21 September 2017 and concerns captured. 1-2-1s to be proactively sought. Guidance to be adapted and published online.	Closed
32	Technical	There is a risk that the IS Vendor (ZIV Automation) cannot deliver the detailed design and build of the solution envisioned by the project team.	Risk ongoing and to be reviewed regularly. Walk-through of revised detailed design for the interim solution is complete. Full solution design agreed. Progress is being made, but not fully resolved yet. Final DERMS upgrade to be delivered December 2020 ahead of Wave 2 trials.	Closed
33	Technical and Commercial	There is a risk of insufficient sharing of data between the project partners.	To be kept under review and within consideration of regulatory requirements. Wave 2 market reporting requirements still being specified, December 2020	Closed
34	Commercial	Adding secondary optimisation may impede delivery of the project's Minimum Viable Product (MVP).	Agreed that secondary optimisation is out of scope for the project's MVP, whilst agreeing to explore options for inclusion without detriment to MVP.	Closed
35	Business readiness	There is a risk of delay if workstream 3 leads are not identified and mobilised in time.	Workstream leads confirmed and delivery plans included within project plan.	Closed
36	Robust plan	There is a risk that the project plan is not effectively driving delivery.	Re-planning underway following delays to delivery and ongoing revision of logic of critical dependencies. Material change request to Ofgem submitted November 2020.	Closed

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37	Commercial	There is a risk that DER will be deterred by the uncertainty regarding how trials will work during 2019/20.	Four participants now in trials at end November 2020 and commissioning of fifth participant underway.	Closed
38	Commercial	There is a risk that we do not have enough budget to deliver the success criteria for DER recruitment.	Criteria met. Steering Committee approved revising the level of contingency allocated to boosting payments to trial participants, reflecting the latest forecast participation level. Publication of the commercial proposition for the trials has been well received.	Closed
39	Commercial	There is a risk that the RMAP advocates a different approach to that planned within the trials.	Engage RMAP on developing approach and consider their feedback in finalising the project's approach. Framework Agreement and Market Procedure now published.	Closed
40	Technical	There is a risk that the IS architecture elements of the detailed design cannot be agreed.	Architecture has been signed off.	Closed
41	Technical	There is a risk that the testing schedule risks delay in delivering SDRC9.4 and the start date for trials.	Review testing requirements for SDRC9.4 (i.e. testing in controlled environment). Align plan with proposed trial design (start dates).	Closed
42	Technical	There is a risk that the project approach to large embedded generators is not agreed.	Steering Committee agreed to engage large embedded generators to gauge their interest. MW despatch to remain under ENCC control. Mvars despatch to be considered through DERMS.	Closed
43	Technical	There is a risk of not having proper Transmission and Distribution data to develop DERMS solution.	Detailed plan developed and progress is being tracked through the project's Technical Question governance approach (Reference "TQ8"). The Technical question approach is used to raise and track resolution of outstanding technical design issues.	Closed
44	Technical	There is a risk that PAS-DERMS interface delivery increases project costs or risks.	Plan and costs agreed for this activity.	Closed
45	Commercial	There is a risk that SDRC9.3 is not delivered in full and on time.	Delivered on time and to quality/scope.	Closed

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46	Commercial	There is a risk of not having clear idea about the interface for Aggregators.	Steering Committee agreed that aggregator approach cannot now be pursued through the available project timescale and budget.	Closed
47	Commercial	There is a risk that the project will incur costs without securing trial results data and insight (if the trials are cancelled after DER complete commissioning tests).	Raised at 24 May 2018 Steering Committee and risk accepted in order to bolster commercial proposition to DER participants.	Closed
48	Technical	There is a risk that ANM in the project area affects performance or on-time delivery of DERMS.	Commitment by ANM project to fund any relevant costs. System delivered with close co-operation with UK Power Networks' ANM project to share labour resources	Closed
49	Technical	There is a risk that the GE CIM export may not be fully tested and may not be compatible with ZIV algorithms/or delay in providing the export.	Project delivery plan rescheduled to minimise delay to the trials caused by delay in CIM Export readiness. Initial GE CIM export accepted and transformed by ZIV in March 2019. IS transfer solution delivered in December 2019 to transfer multiple CIM extracts, and FAT test of CIM import completed in July 2020. January 2020 decision to proceed with live trials without daily CIM import – project identified inclusion would have required data correction activity for whole SPN licence area rather than local to each DER	Closed
50	Technical	There is a risk that DERMS produces inaccurate results due to poor quality data.	See risks 51 and 52.	Closed
51	Technical	There is a risk that DERMS produces inaccurate results due to incorrect inputs. (Data quality – transducers).	More accurate power quality metering data utilised at each DER. Data risks reviewed in order to reframe them more effectively.	Closed

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52	Technical	There is a risk that DERMS produces inaccurate results due to incorrect inputs (data quality – PowerOn).	Data correction and state estimation solutions for network/SCADA data has been investigated, did not need to be implemented for trial, forms part of offline learning. Trial could be delivered based on use of just GSP and DER data with static network model. 1) Key aspects of PowerOn operational model have been updated from PowerFactory (planning model) 2) Missing directional data in PowerOn would in future addressed as part of state estimation.	Closed
53	Technical	There is a risk that the intensity of activity proposed during build/test in 2018 cannot be fully resourced by the available team.	Additional UK Power Networks resource secured for testing and integration.	Closed
54	General	There is a risk that SDRC9.4 delivery is delayed by technical, commercial and/or business readiness.	Delivered on time and to quality/scope.	Closed
55	Technical	There is a risk that the PowerOn upgrade (version number PowerOn Advantage (POA) 6.4.1) will be delayed, including functionality that DERMS requires to get automatic update of the CIM network model.	Priority – liaise with GE and UK Power Networks control room to determine scale of delay, implications of running DERMS before the POA 6.4.1. Upgrade to PowerOn. To investigate whether it may be possible to manually update the CIM model on monthly basis. Update – POA upgrade delivered July 2019.	Closed
56	Technical	There is a risk that no mobile controllers will be available for use in the test lab and this part of the solution will not be used or tested until SIT starts in February 2019.	Mobile controller purchased, therefore risk is closed. Also five customer DER controllers were brought to lab for testing.	Closed
57	General	There is a risk of SDRC9.5 not being delivered on time and with the required scope and quality.	SDRC9.5 delivered on time and to quality/scope. Notified Ofgem of the need to delay publication until completion of the project trials to avoid distorting commercial behaviour of participants during the trials	Closed

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58	General	There is a risk of the 12-monthly report not being delivered on time and with the required scope and quality.	Plan for drafting, review and approval agreed.	Closed
59	Communication	There is a risk that insufficient planning and focus result in a poor 30 October 2018 Showcase event.	Plan agreed and Tracked. Success event delivered.	Closed
60	Commercial	Risk that migration to BAU will be delayed due to the requirement for different commercial arrangements.	New commercial arrangements would be required post-trial. Wave 3 was cancelled – no firm BAU plans. Work underway to develop detailed plan for migrating participants to an enduring solution once the trials finish in 2021. This includes mapping what different approaches might be required for BAU (versus those in the trial), to minimise delay. Also acknowledge to all stakeholders that this is an innovation project and there is an underlying risk that the project may not be successful.	Closed
61	Technical	There is a risk that implementation of new Volt Select 400kV SCADA points from National Grid ESO into UK Power Networks' systems is not successfully completed.	The design was progressed through the project's Technical Question governance approach (reference to this risk is "TQ4") and was delivered in 2019. The Technical question approach is used to raise and track resolution of outstanding technical design issues.	Closed
62	Technical	There is a risk that PAS testing does not meet project objectives on time/in full that ensure nomination, dispatch and settlement functionalities within DERMS.	Discussion held with ZIV and National Grid ESO to agree PAS testing strategy after process definitions are closed (i.e. paper walkthrough meetings). PAS-DERMS pre-production connectivity proven end August 2019. PAS-DERMS business logic testing still to be scheduled.	Closed
63	Not in use			
64	Not in use			
65	Technical	There is a risk that in real time the DER technical availability volume of the reactive power service is inaccurate.	Likelihood and impact deemed low given volume in trial. Mitigation include % of plant in service available signal in list of mandatory signals. Need a process to utilise this in future.	Closed

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66	Business processes	Risk that the WS3 plan does not adequately cover the risks associated with the Staged Delivery approach.	National Grid ESO and UK Power Networks teams have revised WS3 plans for interim and full solution and migration to BAU and appraised the risks for each of these.	Closed
67	Trials	There is a risk that the project risks during the trial delivery phase are not fully documented.	To be developed by the Trial manager at each partner before trial delivery.	Closed
68	Business readiness	There is a risk that the new Power Potential service software and displays may not be installed in the Control Room in time for the trials.	Included within Control Room calendar for 2019.	Closed
69	Business readiness	Risk that the detailed documentation for despatch is not ready on time.	Project lead and despatch lead to walk-through WS3 requirements for interim, full and fall-back manual solutions.	Closed
70	Business readiness	Risk that control room personnel are not trained to use the Power Potential service in time.	Training has begun and further training will be scheduled before each phase of trials.	Closed
71	Business readiness	Risk that the business procedure and detailed documentation for nomination is not ready in time.	To revise plan for WS3 nomination to reflect staged Delivery plan.	Closed
72	Business readiness	Risk that nomination personnel are not trained to use the Power Potential service in time.	To revise plan for WS3 nomination to reflect staged Delivery plan.	Closed
73	Business readiness	Risk that the business procedure and detailed documentation for settlement is not ready in time.	Active power and Wave 1 trials paid in 2020. Some difficulties with payment timescales from National Grid ESO to UK Power Networks – now resolved. Business procedure agreed, Standard Operating Procedure developed. Wave 2 settlement to be delivered in 2021	Closed
74	Business readiness	Risk that settlement personnel are not trained to use the Power Potential service in time.	Finance support trained.	Closed

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75	Business readiness	The testing and training manual for PAS are not ready in time.	PAS team at National Grid ESO to schedule time to develop training manual and delivery training for operational teams for the trials.	Closed
76	Commercial	There is a risk that the active power service being trialled under Power Potential will not align with future EU regulation (TERRE).	Commercial analyst has investigated the commercial requirements for the Trans European Replacement Reserve Exchange project (TERRE) in order to map against the project approach and establish if there is an issue and how to address. Project TERRE is delayed	Closed
77	Commercial	There is a risk that the methodology to test DER capability strays beyond the specification currently drafted in DER Technical requirements	Test specification now written. UK Power Networks committed to only test requirements set out in the DER Requirements. National Grid ESO reviewed the test specification.	Closed
78	Commercial	There is a risk that DER are deterred from involvement in the project due to inconsistent messages from the project team.	FAQs in place as well as agreeing key messages and approaches in 1-2-1s beforehand.	Closed
79	Trials	There is a risk that the trials do not give enough data to provide an adequate conclusion of trial success.	The duration of trials, the number of DER participants and their reactive power capability have all been carefully considered to ensure sufficient data can be captured during the trials.	Closed
80	Trials	There is a risk that generator dispatch impacts trial length or data to determine trial success.	Pre-trial training and monitoring activity during the trials will seek to ensure despatch are fully briefed on the trial service approach and encouraged to deploy the service, where appropriate.	Closed
81	Technical	There is a risk that DER effectiveness for prolonged impacts on voltage is nullified by tap changers (identified from customer's test).	1. Share DER list with Outage Planning and request that taps locked in place where applicable during trials. 2. Discuss design decision with National Grid ESO and then with customer. 3. Plan to program tap changer optimisation in ZIVs algorithm for BAU.	Closed

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82	Technical	Risk of trial delay when migrating from the interim technical solution to the full solution (Wave 1 to Wave 2)	Focused Wave 2 on commercial extension as core bid requirement, rather than demonstrating CIM-based load flows (beyond bid requirement). Wave 2 FAT completed, final defects on pre-prod being addressed, reconfiguration of installed software to Wave 2 version expected to be a few hours.	Closed
83	Technical	There is a risk that the project solution may not be compliant with the Electricity Balancing Guidelines (EBGL) for December 2019.	Reviewed whether existing PAS solution for EBGL for the PAS-STOR delivery is also appropriate for Power Potential	Closed
84	Trials	Risk of lack of resource from requirements and nomination to deliver the Wave 2 trials.	Colleague identified at National Grid ESO to lead on requirements and nomination	Closed
85	Technical	Risk on co-ordination of specific point testing for communications.	Plan to have one test environment for each of the pre-production and production set-up of the technical solution	Closed
86	Technical	Risk of delay if GE fail to deliver RTU Logic on time.	Detailed planning with GE to ensure tracking against key delivery dates	Closed
87	Trials	Risk that trials take place at time that historically has low service requirements	Review trial calendar and implications on likely operational scenarios occurring.	Closed
88	Technical	Risk that test platform resource to commission not available on time	Delivery rescheduled with test resource allocated.	Closed
89	Commercial	Risk of delays to DER signing Framework Agreement and variation to Connection Agreement	FAQs developed to address common questions and ongoing stakeholder engagement to close out queries	Closed
90	Commercial	Delay in DER studies	Contractor resource in place to facilitate efficient progress of DER studies	Closed
91	Technical	Risk that the SCADA data quality is poor	For trial, data correction algorithm to be applied (see risk 50). For BAU, state estimator approach to be implemented – initial version implemented as described in SDRC 9.4	Closed

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92	General	Risk of a freeze in system changes during Brexit transition	Corporate contingency planning has established potential two week freeze in system change if a disorderly Brexit takes place.	Closed
93	Financial	Insufficient budget to deliver project due to extended project duration	Steering Committee approved allocation of contingency and business funds to enable delivery of the extended project through to completion and close-down in 2020. Material change request submitted.	Closed
94	Technical	PAS-DERMS interface risks	Delivered – PAS-IIB-DERMS connectivity test completed end August 2019, functional integration tests completed August 2020, live connection established October 2020	Closed
95	Technical	Risk of delay to IIB/ESB solution delivery	Delivered – PAS-IIB-DERMS connectivity test completed end August 2019	Closed
96	Technical	Risk of project not being given high enough priority to mobilise UK Power Networks resource	Continuous monitoring with operational teams and against other projects, including escalation to senior management. Introduced joint programme delivery with ANM project in 2020.	Closed
97	Technical	Risk of Outage Planning activity being delivered late	Risk to Full solution (considering synergies with the UK Power Networks Network Vision project), activity for DERMS Interim Solution already delivered	Closed
98	Technical	Risk of delay in securing release of the User Interface design	DER user interface being design specified in early 2019 for all waves.	Closed
99	Technical	Risk of delays to ICCP readiness	ICCP links delivered summer 2019	Closed
100	Technical	Risk of delays in ICCP-PowerOn-RTU	ICCP-PowerOn-RTU signal integration proven	Closed
101	Commercial	Wave 2 Market Reporting not agreed with DER before Wave 2 trial start	National Grid ESO team to add	Closed
102	Technical	Active Power service not being developed with PAS	Alternative approach for technical trial agreed DERMS-DER with National Grid ESO liaison	Closed

UK Power Networks, Energy House, Carrier Business Park
Hazelwick Ave,Three Bridges, Crawley, West Sussex, RH10 1EX

www.ukpowernetworks.co.uk

Faraday House, Warwick Technology Park,
Gallows Hill, Warwick, CV34 6DA

www.nationalgrideso.com