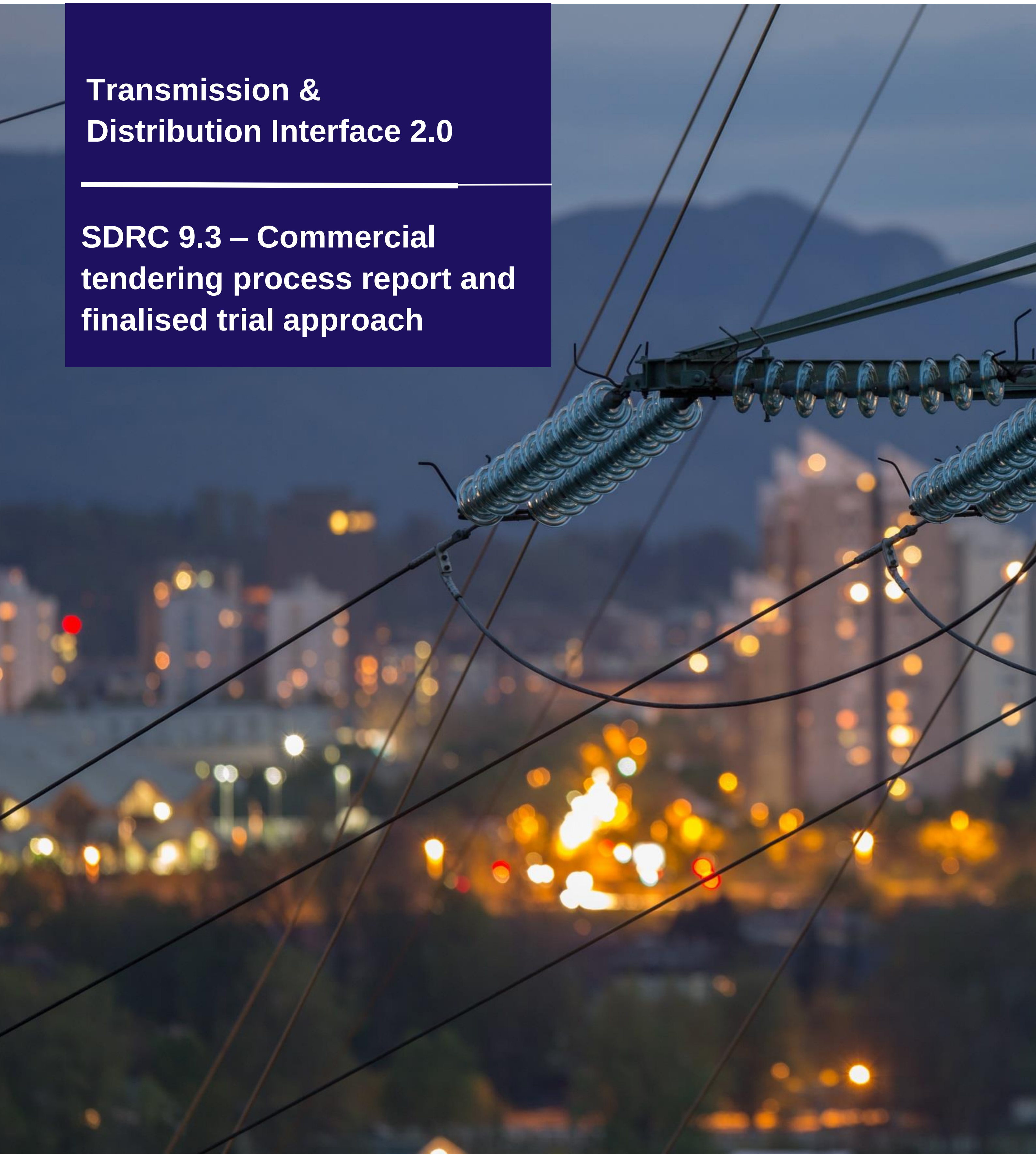
# Transmission & Distribution Interface 2.0

## SDRC 9.3 – Commercial tendering process report and finalised trial approach



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# Definition of terms

| Term | Definition |
|---|---|
| **AC** | Alternating Current |
| **AEMO** | Australian Energy Market Operator |
| **ANM** | Active Network Management |
| **ANN** | Artificial Neural Networks |
| **AVC** | Automatic Voltage Control |
| **BCV** | Business Continuous Volume |
| **CSC** | Carbon Source Converter |
| **CIM** | Common Information Model |
| **CPU** | Central Processing Unit |
| **DC** | Direct Current |
| **DERs** | Distributed Energy Resources |
| **DERM** | Distributed Energy Resources Management |
| **DERMS** | Distributed Energy Resources Management System |
| **DG** | Distributed Generation |
| **DMS** | Distribution Management System |
| **DNO** | Distribution Network Operator |
| **DR** | Disaster Recovery |
| **DRAM** | Demand Response Auction Mechanism |
| **DSO** | Distribution System Operator |
| **EFA** | Electricity Forward Agreement |
| **EMS** | Energy Management System |
| **ENA** | Energy Network Association |
| **ENCC** | Electricity National Control Centre |
| **ERPS** | Enhanced Reactive Power Service |
| **ESO** | Electricity System Operator |
| **FC** | Fibre Cards |
| **ENTSO-E** | European Network of Transmission System Operators for Electricity |
| **FEP** | Front End Processors |
| **FFR** | Fast Frequency Response |
| **FTP** | File Transfer Protocol |
| **GB** | Great Britain |
| **GDPR** | General Data Protection Regulation |
| **GE** | General Electric |

| Term | Definition |
|---|---|
| **GIS** | Geographic Information System |
| **GSP** | Grid Supply Point |
| **GW** | Gigawatt |
| **HTTP** | Hypertext Transfer Protocol |
| **HTTPS** | Secured Hypertext Transfer Protocol |
| **HVDC** | High Voltage Direct Current |
| **ICT** | Information Communication Technology |
| **ICCP** | Inter-Control Centre Communications Protocol |
| **IEC** | International Electrotechnical Commission |
| **IP** | Internet Protocol |
| **IPS** | Secure Internet Protocol |
| **ISO** | International Standards Organisation |
| **IT** | Information Technology |
| **KASM** | Kent Active System Management |
| **Mvar** | Mega Volt Ampere Reactive |
| **MVP** | Minimum Viable Product |
| **MW** | Mega Watt |
| **NAP** | Network Access Planning |
| **NSCAS** | Network Support and Control Ancillary Services (Australia) |
| **NG** | National Grid |
| **NMS** | Network Management System |
| **OPF** | Optimal Power Flow |
| **OS** | Operating System |
| **P** | Active Power in Megawatts |
| **PACE** | Police and Criminal Evidence Act |
| **PC** | Personal Computer |
| **PDU** | Power Distribution Unit |
| **PED** | Personal Electronic Devices |
| **PF** | Power Factor |
| **PKI** | Performance Key Indicators |
| **POC** | Point of Connection |
| **PPA** | Power Purchasing Agreement |
| **PV** | Photovoltaic farm |
| **Q** | Reactive Power in Megavars |
| **RAID** | Redundant Array of Independent Disks |

| Term | Definition |
|---|---|
| **RDP** | Regional Development Programmes |
| **ROC** | Renewable Obligation Certificate |
| **RPO** | Recovery Point Objectives |
| **RTO** | Recovery Time Objectives |
| **RTU** | Remote Terminal Unit |
| **SAN** | Storage Area Network |
| **SCADA** | Supervisory Control and Data Acquisition |
| **SCOPF** | Security Constrained Optimal Power Flow |
| **SCP** | Secure Copy Protocol |
| **SDRC** | Successful Delivery Reward Criteria |
| **SFTP** | Secure File Transfer Protocol |
| **SGAM** | Smart Grid Architecture Model |
| **SO** | System Operator |
| **SOC** | Security Operations Centre |
| **SQSS** | Security and Quality of Supply Standard |
| **SSH** | Secure Shell |
| **STOR** | Short Time Operating Reserve |
| **SVC** | Static Var compensator |
| **STATCOM** | Static Synchronous Compensator |
| **TCSS** | Technical Characteristics Submission Spreadsheet |
| **TDI** | Transmission and Distribution Interface |
| **TNCC** | Transmission Network Control Centre |
| **TSO** | Transmission System Operator |
| **Tx** | Transformer |
| **UK** | United Kingdom |
| **UKPN** | UK Power Networks |
| **VARs** | Volt Ampere Reactive |
| **VLAN** | Virtual LAN |
| **VM** | Virtual Machine |
| **VSC** | Voltage Source Converter |
| **WAN** | Wide Area Network |

# 1. Executive summary

### Context

The purpose of this paper is to provide evidence that the Power Potential project has delivered on the criteria required to successfully achieve the third reporting milestone for the project, known as *SDRC 9.3* or *Commercial tendering process report and finalised trials approach***.** It outlines the engagement on the Power Potential services and the approach to trials that will be taken when the project is demonstrated in 2019.The evidence required is:

- Report on tendering approach, including technical and contractual requirements for participation, barriers to entry and measures to alleviate these.
- Proposed commercial framework and interaction with SO and DNO incentives.
- Review of technologies and volumes under contract.
- Initial forecasts of availability and utilisation volumes.
- Signed commercial contracts.
- Trials approach and methodology.

### Executive summary

- Power Potential is a Network Innovation Competition (NIC) project trialling the use of Distributed Energy Resources (DERs) to support the management of transmission network constraints through the development of two commercial services:
    - dynamic voltage control, known as the reactive power service
    - active power.
- Independent modelling by Imperial College has confirmed that this approach is technically sound and that a competitive commercial framework can be trialled in the trial region.
- Joint engagement by National Grid and UK Power Networks has raised interest levels amongst DERs in the trial region and provided them with the opportunity to influence the design of the services and trials.
- The formation of a Regional Market Advisory Panel has enabled the project team to consult with a range of industry experts to ensure that their views are considered when designing the trials and developing services which are fit for the future and will contribute to whole system learning.
- An Inter-Operator Agreement[1] has been signed by National Grid and UK Power Networks to govern service delivery during the trial. This demonstrates the project's achievement of the SDRC9.3 requirement on contract signature. In addition, an associated framework agreement is in the final development stage for DERs to contract service delivery to UK Power Networks, and will be published shortly. At bid concept, it was anticipated a tender for services would have been run at this stage in the project and long-term contracts with DERs signed. However, the finalised commercial proposition will trial a daily auction approach, so DERs are now anticipated to sign on to a framework agreement to enable them to participate in the auctions. DER were consulted in the drafting of the framework agreement, and their feedback has been incorporated in the revised version. At this stage, nine DERs are actively engaged and the project team is working with them towards signing onto the terms of the service in the coming months.

[1] The project does not expect to publish the Inter-Operator Agreement but will make it available to the Authority on request.

- If all interested and eligible DERs sign up for the trial, this translates into an anticipated volume of 121 Mvar lead capability and 113 Mvar lag capability for the reactive power service, and 95 MW maximum capability for the active power service. These values have been calculated as per the DER recruitment status on 15 June 2018. This is sufficient volume to demonstrate the technical proof of concept for Power Potential.[2]
- A market framework to trial the world's first regional reactive power market is in place. Cambridge University provided academic input to ensure international best practice and competitive auction design were considered in the design of our services.
- The interaction of Power Potential with SO and DNO incentives for the trial year is understood, with further work within the project related to possible cost recovery mechanisms in the future.
- During 2019, the demonstration project will run trials made up of three waves, each with a different objective and associated commercial framework. The trials are designed to maximise participation in the project, whilst ensuring the objectives of the trials could be met i.e. to prove the technical concept of Power Potential, and to test the market concept of this approach through price discovery.

[2] The above volumes do not include the grid-code compliant generators embedded in the distribution network in the trial area, which may be instructed by National Grid under the Obligatory Reactive Power Service. However, the plant dispatch for reactive power through DERMS is currently being explored in the Power Potential project.

# 2. Introduction

## 2.1 Background and project objectives

### 2.1.1 Context and challenge

The south-east of England has seen a significant growth in DER connections to the distribution network due to the region's geographical position and excellent solar and wind resources.

The south-east coast transmission network interfaces with UK Power Networks' distribution system at four GSPs: Bolney, Ninfield, Sellindge and Canterbury North, located in Sussex and Kent.

Apart from the growth in DER, the south-east coast network is influenced by the presence of two interconnectors with continental Europe and plans for two more in the future. The south-east coast network includes 2 GW[3] of peak demand and 5.5 GW of large generation including wind farms, nuclear power stations and a combined cycle gas-fired power plant. Existing and future interconnection and generation projects include:

- Interconnectors:
  - **IFA HVDC** (LCC, two bipolar links)**:** connected at Sellindge substation.
  - **NEMO HVDC** (VSC): to be connected at Richborough substation (expected in 2019).
  - **ELECLINK HVDC** (VSC): to be connected at Sellindge substation (expected in the future).

- Generators connected at transmission level:
  - **Dungeness** two machines: connected at Dungeness substation.

- Offshore wind farms connected at transmission level:
  - **London Array:** connected at Cleve Hill substation at 400 kV.
  - **Rampion:** connected to Bolney substation via Twineham substation at 150 kV.

As a result of the growing levels of intermittent renewable generation, National Grid is facing increasing operational challenges managing the voltage and thermal limitations for certain network conditions, while still being able to transfer electricity to the country's load centres. Capacity to connect more generation on the south-east of England, namely at the Grid Supply Points (GSPs) in Canterbury, Sellindge, Ninfield and Bolney, is being restricted due to upstream constraints on National Grid's transmission network. The constraints include:

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

The high voltage at low load scenario now occurs regularly at weekends in the summer period, but the voltage stability constraint is most prominent in the event that a fault occurs on the route between Canterbury and Kemsley. This leaves only one long westerly route to deliver the south-east's green energy into London.

If such a fault occurs the consequences can be very serious for the system. The line remaining after the fault will be required to transfer a significant amount of power. This double circuit can

[3] Figures derived from National Grid's Electricity 10-year statement 2017

be characterised as a long radial line, and its electrical characteristics will lead to a rapid voltage drop across the network seconds after the fault.

If the voltage drop is not contained in time, this could lead to voltage collapse and, ultimately, a 'blackout' of the network. Even if a full collapse is averted, a dramatic deviation of the transmission voltage away from statutory limits can cause severe problems. Domestic appliances, building controls, elevators, air conditioning, and small generators, for example, might fail or trip, even though they are connected at a lower voltage on the distribution network. These upstream constraints lead to the following emerging regional challenges:

- Fewer low carbon technologies can connect in the area.
- High risks due to the operational complexity which can lead to the situation of losing part the network, which can further lead to voltage collapse of the whole network.
- Higher costs of managing transmission constraints.

## 2.2 Power Potential (TDI 2.0) project approach

To provide voltage support in the area, increasing reactive compensation is needed. DERs connected to the distribution network in the area have the potential to provide reactive and active power services to the transmission system.

Transmission and Distribution Interface 2.0 (TDI 2.0), known as Power Potential, aims to give National Grid access to resources connected to UK Power Networks' south-east network to provide additional operational tools for managing voltage and thermal transmission constraints and assess their relative impact on the cost of solving transmission constraints. The project aims to create market access for DERs to participate in ancillary service provision to National Grid via UK Power Networks' coordination. It is envisaged that the services provided by DERs will alleviate both transmission constraints, while considering constraints in the distribution network. This will unlock whole systems benefits such as additional network capacity and operational cost savings to customers.

The Power Potential project will create a regional reactive power market, the first of its kind in Great Britain, and will help defer network reinforcement needs in the transmission system. The Grid Supply Points (GSPs) considered in this project are Canterbury North, Sellindge, Ninfield and Bolney.

The project will help enable more low carbon resources to connect in the south-east and give new and existing DERs the opportunity of providing services to National Grid and access additional revenue streams. Services procured from DERs will be coordinated so that the operation of the distribution and transmission networks are kept within operational limits and constraints are not breached. When deployed, the Power Potential method is expected to deliver 3,720 MW of additional generation in the area by 2050 and savings of £412m for Great Britain's energy consumers by 2050.

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

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

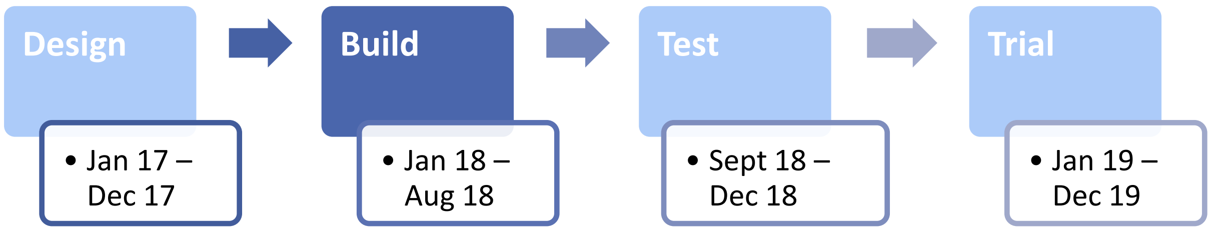
At a high level the DERMS solution is envisaged to work as follows:

- Gather commercial availability, capability and bids from each DER.
- Run power flow assessments to calculate possible availability of each service at the GSPs. Once the assessment is complete, a range of service availability and costs will be presented to National Grid as intra-day availability (or a 24-hour rolling window) taking into consideration DER bids, their effectiveness and what the distribution network can allow at the time of service due to current running arrangements. With this information, the GB System Operator will decide the level of services to be procured.
- On the day of the response, National Grid will instruct the services to UK Power Networks and the DERMS solution will instruct each DER to change their set-point as required and monitor their response.

## 2.3 Project timeline

The project will be delivered in the following phases:

Figure 1: Project timeline




The project's design phase is complete. The technical high level design was published in July 2017 (addressing the scope of the project's Successful Delivery Reward Criteria SDRC 9.1), followed by the project's stage gate 1: the commercial and detailed technical design in December 2017 (SDRC 9.2)[4]. SDRC 9.3 represents the project's stage gate 2 (commercial tendering process report and finalised trials approach) and its purpose is described in section 2.3.

[4] Both reports are available to download at www.nationalgrid.com/powerpotential

Work stream 1 (technical) has now successfully completed the DERMS design and the supporting information systems architecture, the design phase of Power Potential.

The DERMS software development has started, and several strands of functionality have been demonstrated by the software vendor. Good progress has been made in developing the active and reactive power service modules. The next phase of the DERMS to develop the future availability functionality. Together the service and future availability modules incorporate the functionality that satisfies the commercial requirements.

Considering the information systems aspects, an Inter-Control Center Protocol (ICCP) link with UK Power Networks' network control and SCADA system has been set up to link to the DERMS. This is in addition to re-using an existing ICCP link for data exchange with National Grid's set up during the KASM project. Progress has been made on designing:

- National Grid's Platform for Ancillary Services (PAS) system and its messaging to the DERMS.
- The automatic import to the DERMS of UK Power Networks' PowerOn network model.
- SCADA data in a Common Information Model (CIM)-compliant format.

In parallel, the project has defined the testing strategy and has been preparing test environments (cloud based and pre-production) to support all the testing phases. The goal of the testing strategy is to prepare the technical solution and confirm its readiness for trials in 2019.

Activity is progressing towards the project's Stage Gate 3: Customer Readiness Report and Performance of the Technical Solution in Controlled Environment (SDRC 9.4). The testing of the DERMS described in the last paragraph includes defining and preparing the business readiness of both project partners (National Grid and UK Power Networks) to proceed to trials in 2019.

### 2.4 Purpose of the document

This document describes the project's commercial solution and finalised trial approach. It provides greater detail on the commercial framework for the trials, including technical and contractual requirements for participation and the trial design. The report details the progress made on engagement with potential trial participants, their commitment to the trials and analysis of the technologies and volumes anticipated to participate in the trials and initial forecasts of availability and utilisation volumes.

An integral theme in developing and finalising the commercial framework and trial design has been engaging with stakeholders, consultation on project design, gathering feedback and refining the project's approach. This is demonstrated throughout the following chapters.

The key evidence criteria for SDRC 9.3 are presented in Table 1.

Table 1: Key evidence criteria of SDRC 9.3 and corresponding sections of the document

| Criteria | Evidence | Section |
|---|---|---|
| **Commercial tendering process report and finalised trial approach** | • Report on tendering approach<br>• Technical and contractual requirements for participation | Chapter 5<br>Chapter 5 |
| | • Proposed commercial framework and interaction with SO and DNO incentives | Chapter 3 &<br>Chapter 6<br>Link to Imperial College London report<br>Link to University of Cambridge report |
| | • Review of technologies and volumes under contract | Chapter 4 |
| | • Initial forecasts of availability and utilisation volumes | Chapter 8 |
| | • Signed contracts | Executive Summary |
| | • Trials approach and methodology | Chapter 7 |

# 3. Insight from Imperial College London research

The main objective of Imperial College's research milestone for this report was to inform the development of market arrangements and the commercial framework both at transmission and distribution levels. This considered selecting the most cost-effective portfolio of contracts for the provision of reactive power support based on offers from different service providers (range of virtual power plants and conventional sources). The contracted reactive capacity should provide adequate resources for delivery of voltage control across a set of loading conditions, while considering credible contingencies. The market framework considers dynamic availability and cost characteristics of virtual power plants driven by changes in the local distribution system conditions in coordination with the state of the transmission network. The commercial arrangement also considers differences in bids that market participants would offer in the auction process.

To achieve the objective, a sequential two-stage approach has been developed and used to simulate some illustrative cases to demonstrate its feasibility and effectiveness.
The first step is to aggregate the technical and economic characteristics of the DERs, taking into consideration the distribution network constraints while optimising the network assets and control settings.

The second step involves the application of a security constrained optimal power flow (SCOPF) algorithm. This is to identify the optimal portfolio of commercial contracts in the national reactive capacity market of different durations, considering temporal changes in cost and capability of virtual power plants, to support secure transmission system operation. From the modelling and analysis carried out, the following key findings were identified:

1. The studies demonstrate that DERs connected to the local distribution network, in the scope of the Power Potential project, could be used to provide reactive power services and support in securing operation of the transmission network.
2. The sequential reactive power market framework using the virtual power plants approach to aggregate DER capacity and local distribution network characteristics, is technically sound. The case studies demonstrate successfully the feasibility of the concept. The application of this concept will provide DERs with the opportunities to access ancillary service markets at the local level and national level.
3. The value of the reactive power of virtual power plants varies with time, location, demand and system conditions. As DERs are highly distributed across the system compared to large-scale transmission connected generators, DERs can provide reactive sources more effectively as they can be closer electrically to the part of the system that needs support.
4. The importance of distribution active network management on dynamic capabilities of the virtual power plant has been demonstrated in the studies. This suggests that:
   - (i) It would be beneficial that the DSO optimises network operation to maximise the DER access to transmission ancillary service markets (i.e. reactive power market in the context of Power Potential) and local energy markets. This demonstrates that it would be beneficial that the role and responsibility of the DSO evolve to facilitate access for DERs to transmission ancillary service markets.
   - (ii) Distribution network assets can provide reactive power support to the transmission network. This resource could play a role in the reactive power market. The capability of network assets can be aggregated but it requires the development of a commercial framework that can remunerate the services from distribution assets.

5. The networks studied in Power Potential can provide access of DERs to the intact system.
6. Virtual power plants reactive power dispatch is sensitive to price, due to the high distribution network capacity, which will facilitate competition in the local reactive power market.
7. The reactive capability of virtual power plants is dynamic and changes according to local conditions in the distribution network. This requires real-time monitoring and active management of the resources.

Imperial College's research to date demonstrates that the Power Potential approach has potential to add value to the end consumer. The report from Imperial College London can be accessed here.

# 4. Stakeholder engagement

## 4.1 Introduction

The project team has continued to engage with key stakeholders building on the detail presented in SDRC 9.2. This chapter outlines the process that the project team has made to maximise DER participation ahead of the trial in 2019. This engagement strategy provides confidence that the Power Potential service will make a material contribution to voltage control and constraint management on the National Electricity Transmission System, that DERs can financially gain from the project, and consumer savings can be made.

The engagement process has ensured that potential DERs being targeted for participation in the trial are kept up to date and are involved/consulted on the progress of developing the trial.

The insight from engagement with DERs, aggregators and the project's Regional Market Advisory Panel has substantially informed the development of the commercial proposition for DERs to participate in the project's trials as described in chapter 5. This input contributed to the continuing development of the commercial proposition for the trial, of the proposed Framework Agreement between UK Power Networks and DER participating in the trials and a supporting 'Market procedures' document.

This chapter will also cover the success criteria for the project, based on which the engagement strategy has been developed to target the maximum volumes across several technologies.

## 4.2 Success criteria

In autumn 2017, a set of success criteria was agreed amongst the project team (see table 2) to provide a guide of how successful recruitment, that would ensure a successful trial, would be measured. This allowed the project's commercial work stream to develop a tailored approach to the DER recruitment/engagement process.

Table 2: Success criteria

| Success criteria | | |
|---|---|---|
| **Variable** | Justification for variable/proposed measure | Assessment of status vs success criteria |
| **Minimum measurable change of reactive power at GSP** | To demonstrate embedded generation connected to the distribution network can provide reactive power on a scale that can impact GSP | Based on current TCSS submissions, this would be achieved, and continuing engagement to convert this into contract signature. Success to be measured during 2019 trials. |
| **Volume of providers** | To maximise learning from trial, gaining sufficient data on the delivery of an innovating service.<br>Number of service providers 10 (target) 15 (stretch) | Received expressions of interest from 13 companies representing 19 sites. Discussions with other potential participants ongoing |
| **Technology Type** | Diverse range of technologies including at least one of each technology type amongst the connectees in the region.<br>This includes:<br>Solar, Storage, Wind, CHP and Largescale synchronous | Expressions of interest received from all technology types |

| Success criteria | | |
|---|---|---|
| **Variable** | **Justification for variable/proposed measure** | **Assessment of status vs success criteria** |
| **Active Power capacity (MW)** | 130 MW for trial region. This assumption was used in the bid Cost benefit analysis. It was assumed that virtual power plant of 130 MW in trial area will provide enough Mvars to be able see the changes of reactive power flow on the transmission system | Approximately 95 MW available based on expressions of interest |

These success criteria are being used to drive the engagement strategy to recruit sufficient participants for the Power Potential trials. In the following sections the key activities are described that have been undertaken to meet these agreed success criteria.

### 4.3 Power Potential engagement strategy

The engagement process is being led jointly by UK Power Networks and National Grid. Both parties have utilised existing relationships with providers within the trial region, through the Business Development and Contracts and Settlements team within National Grid and the project's Stakeholder Engagement team at UK Power Networks. Table 3 below outlines the engagement activities that the team has undertaken to keep DERs informed of project progress, captured their views and established their interest in participating in the Power Potential trials.

**Table 3: Engagement activities for potential trial participants**

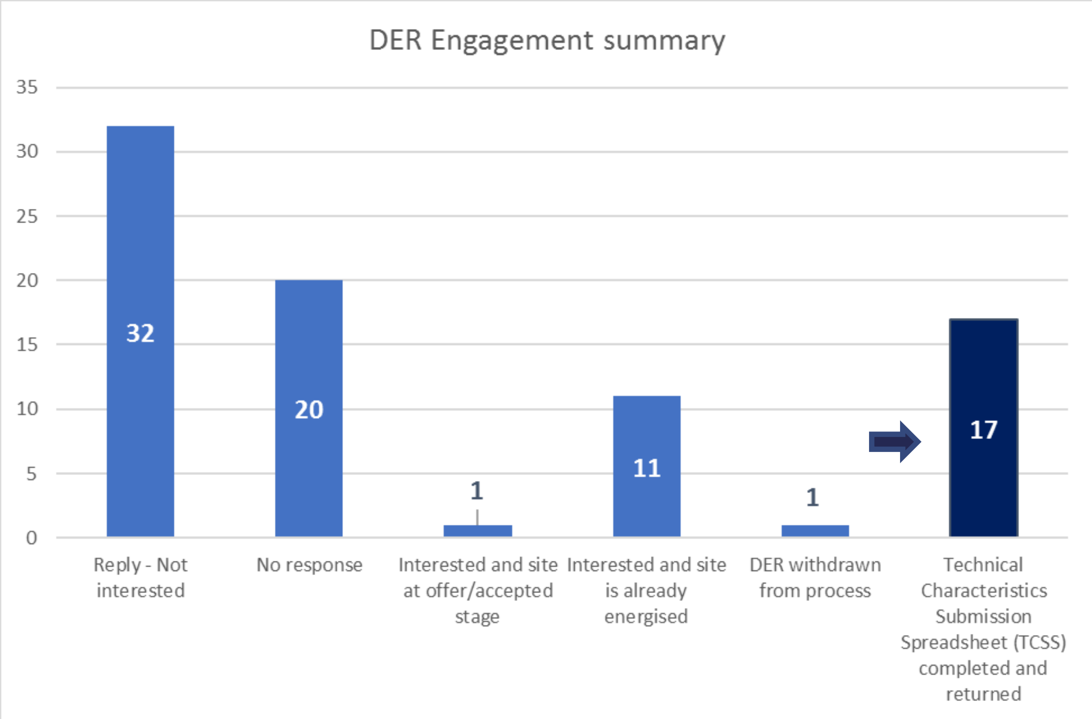
| Theme | Engagement activities |
|---|---|
| **Identify target audience** | • Direct contact with potential trial participants<br>• Project explained and DER's interest gauged<br>• Inclusion on mailing list for regular Power Potential updates<br>• Power Potential website created for easy access to information<br>• Dedicated email address created to monitor queries |
| **Expressions of interest request** | • TCSS created with a Technical Guidance document, enabling the collation of key data to establish DER capability<br>• Draft Heads of Terms published<br>• Providers offered additional one-to-one support to complete TCSS<br>• Provider requested were asked to provide initial thoughts on commercial position |
| **Webinars & one-to-ones** | • Four webinars held to update DER on the project, with materials published on the project website[5]:<br>21 September 2017 Webinar**. Slides** and **summary document.**<br>29 January 2018 Webinar. **Slides** and **Summary document.**<br>26 March 2018 Webinar. **Slides** and **Transcript.**<br>16 May 2018 Webinar. **Slides** and **Transcript.**<br>• Follow up one-to-one sessions held with DERs as requested |

[5] www.nationalgrid.com/powerpotential

| Theme | Engagement activities |
|---|---|
| | • Targeted one-to-one sessions held with DERs that submitted a TCSS<br>• One-to-one sessions covered DER's communications requirements, testing and commercial issues |
| **Regional Market Advisory Panel** | • Bringing together a diverse group with expertise throughout the electricity generation and distribution value chain, led by a high profile and independent chair.<br>• Discussion and challenges to date have focused on key commercial themes within the project including on the development of the trial design, payment structures and contractual framework. |
| **Surgeries and consultation** | • Surgeries held to share commercial proposition with DERs in greater detail<br>• Opportunity for DERs to challenge and help shape the commercial proposition<br>• Consultation undertaken with DERs on the proposed provider agreement prior to developing the final contract |
| **Ongoing Engagement** | • Ongoing targeted engagement with DERs up to signing a contract<br>• Ongoing engagement with DERs, post contract signature to support:<br>    ◦ any upgrade works<br>    ◦ commissioning tests<br>    ◦ communications installation<br>    ◦ readiness for trial<br>    ◦ settlements<br>    ◦ inform them of key dates |
| **Communications strategy to support engagement activity** | • Presentations to industry conferences and associations including the Power Responsive Forum, Future Energy Conference and Renewable Energy Association's Smart Future Group.<br>• Social media coverage to raise the profile of the project, published project materials, project webinars and presentations at conferences.<br>• Articles in online and printed trade publications<br>• Submitting entries to awards schemes to raise the profile of the project within industry, as well as the technical and commercial innovations that the project intends to bring to market.<br>• Submitting industry papers and presenting at industry events to further leverage the project concept and deliverables |

Over the last twelve months the team has identified and engaged potential trial participants within the trial region via emails, meetings, one to one discussions, webinars and targeted material published on our website. The project team's progress in engaging the 82 identified potential participants in the area is summarised in Figure 2. This included engaging with two large grid code compliant generators embedded in the distribution network.

**Figure 2: DER's engagement levels and interest in participation in the project.**




The DER capacity in MW at each Grid Supply Point in the area is presented in table 4.

**Table 4: South-east Power Potential target market engagement pipeline**

| Participant volumes | Quantity (sites) | Capacity (MW) |
|---|---|---|
| **Number of generators in area (in scope)** | 65 | 1,663 |
| **Reply - Not interested** | 32 | 1,183 |
| **No response** | 20 | 197 |
| **Interested and site at offer/accepted stage** | 1 | 18 |
| **Interested and site is already energised** | 11 | 262 |
| **DER withdrawn from process** | 1 | 3 |
| **Technical Characteristics Submission Spreadsheet (TCSS) completed and returned** | 17 | 352 |

In addition to engagement within the trial area, the project has also received interest from DERs and aggregators with sites outside of the project's geographic area. This demonstrates the potential for expansion of the concept to more areas if the trials prove successful. This interest is reflected in the level of registrations and participation in the project's webinars shown in table 5.

During 2018, the project has held three webinars to keep DERs informed of all relevant aspects of the project. The project has received significant interest in these. They informed potential trial participants of latest updates, key milestones and shared the timeline for delivery up to the start of the trial.

Table 5: Power Potential webinars

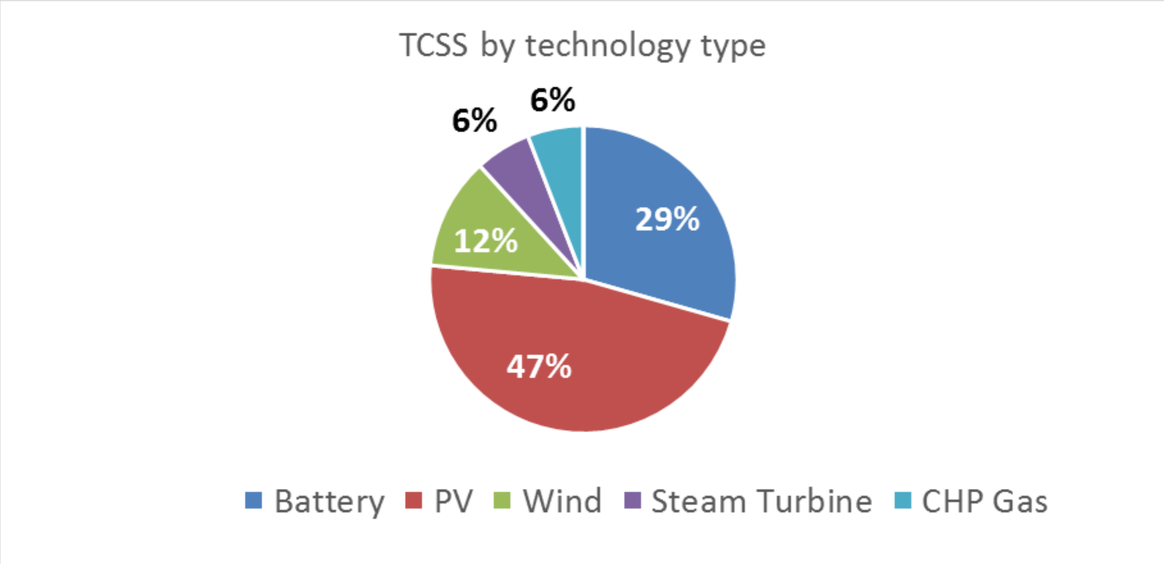
| Webinar | # of Participants registered and joined | Content |
|---|---|---|
| **29 January 2019** | 166 registered<br>65 joined | • Project introduction / customer and stakeholder benefit<br>• Technical update on the DERMS<br>• Requirements for participating: launching the Technical Characteristics Submission Spreadsheet (TCSS)<br>• Contractual framework<br>• Market value |
| **26 March 2018** | 83 registered<br>37 joined | • Update on project progress<br>• Update technical submissions received and queries raised<br>• DER Interface requirements<br>• Testing |
| **16 May 2018** | 49 registered<br>16 joined | • Trial design<br>• Commercial proposition<br>• Update on common queries (Distribution use of system charges and power factor studies) |

## 4.4 Power Potential Recruitment to date

Acting on the engagement strategy above, and based on the levels of interest expressed via the Power Potential *Technical Characteristics Submission Spreadsheet* (TCSS) request, the project team is engaging directly with several potential trial participants.

To date (15 June 2018), a total of 17 TCSSs have been completed and returned, representing 17 sites across varying technologies connected (or expected to be connected) within the trial region, totalling 353 MW. This data does not take into consideration network constraints and operational restrictions, which is discussed later in the report (section eight). The varying technologies represented by the submissions to date are depicted in figure 3.

Figure 3: Technology types represented in technical submissions




Additional analysis of the technical data submitted by DER participants to determine forecasted volumes of active and reactive power for the trials can be found in chapter 8.

Engagement with these DER and all other potential participants will continue up to and during the trial period. Figure 4 outlines the various stages that interested DERs follow to ensure that their readiness to participate in the Power Potential trials can be confirmed by the end of 2018.

Figure 4: DER stages for trial readiness

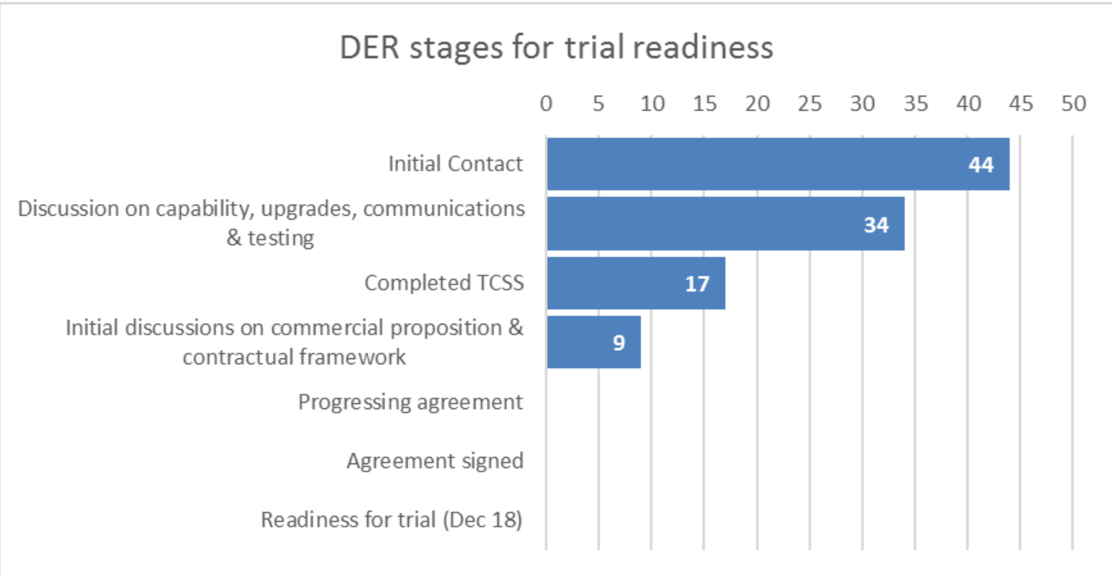


Figure 5 shows a DER pathway to participation and key milestones for DERs leading up to, and during the trial.

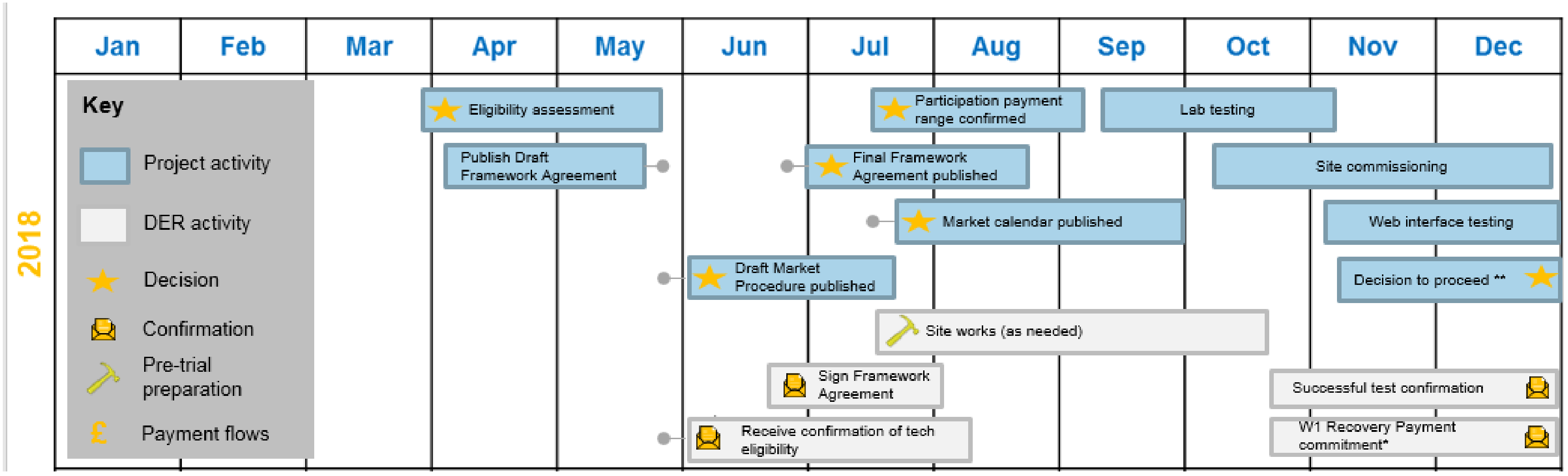
The timeline includes project activity, DER activity, key decision points, confirmation points to DERs, pre-trial preparation activities and payment flows. We are confirming DER's eligibility for the trial with all interested trial participants in June, using data declared by each DER on the *Technical Characteristics Submission Spreadsheet* and intend to confirm technical eligibility. The main technical eligibility criteria are:

- Connected to the distribution network for one of the Power Potential GSPs at 11 kV or above.
- Above the minimum installed capacity of 1 MW.
- Assumed they can achieve 90% of the possible change from full lead (importing reactive power) capability to full lag (exporting reactive power) capability within two seconds (this will be verified as part of commissioning and performance testing).
- Already energised (to allow participation in site commissioning later in 2018).

The project continues to engage with all DERs, including those which are not yet energised or not yet ready to participate. However, these participants are advised that they may not be able to fully access wave 1 participation payments if other projects are commissioned earlier.

The market calendar for the trials which includes further details of the timing of the 2019 trials, will be published this summer. Once DERs have signed provider agreements, site works may then be necessary for DERs to prepare to deliver the service. In the autumn, we will offer laboratory testing to DERs. Site commissioning will then take place and all DERs will receive confirmation following successful testing. Successful demonstration of service delivery will then qualify DERs to receive the wave 1 recovery payment. Web interface testing will also be required and DERs will be invited to participate in this.

Figure 5: A summary of the pathway through 2018 to participation in the 2019 Power Potential Trials



## 4.5 Evidence of engagement activities

Some examples of engagement activities undertaken since SDRC 9.2 was published are illustrated below. They demonstrate encouragement to participate in the Power Potential trials and raising the profile of the project's innovative concept.

**Figure 6: Social media coverage on Twitter promoting the publication of the project's webinar materials onto the project website**

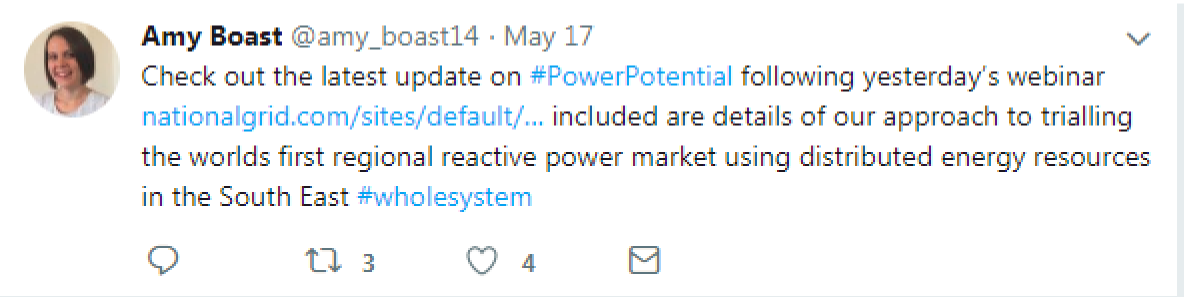



**Figure 7: Social media coverage promoting the project's March 2018 webinar for DER to find out more about the commercial arrangements for the 2019 trials**

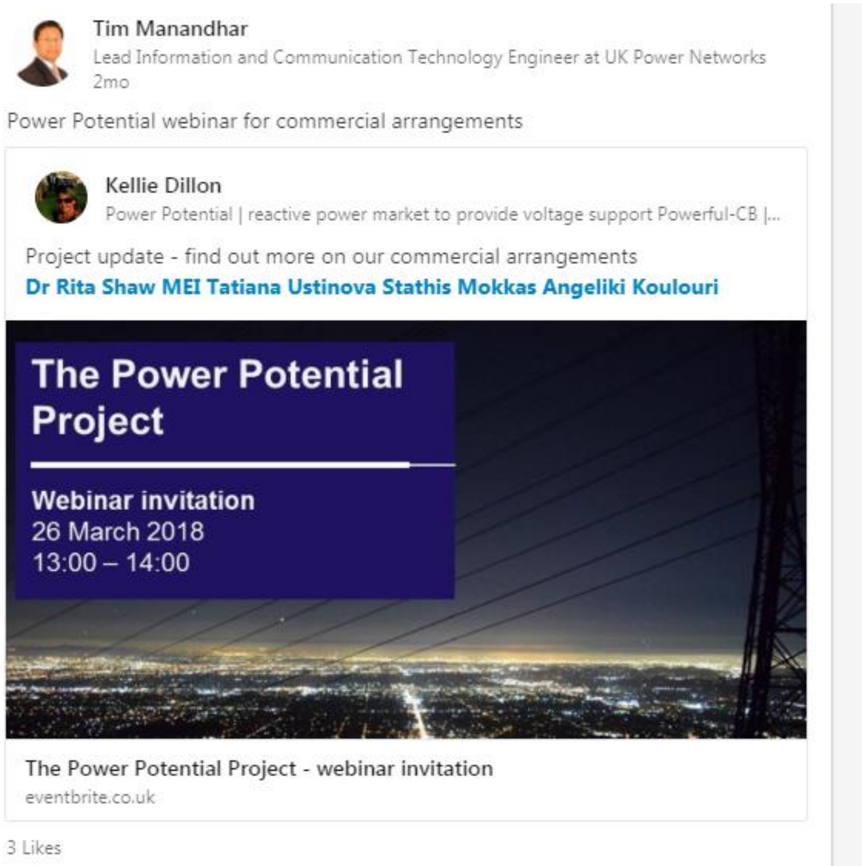


**Figure 8: Social media coverage on LinkedIn promoting the project's May 2018 webinar for DER, providing the latest updates to the commercial proposition to participate in the trials.**


**Figure 9: Social media coverage on Linked highlighting the commercial proposition and inviting**

**Figure 10: Social media coverage on Twitter highlighting the project's success at being shortlisted for 'the best use of emerging / new technology' award at the Real-IT Awards**


**Figure 11: Dr Inma Martinez, National Grid, presenting the Power Potential project at the All Energy Conference, Glasgow**

**Figure 12: Dr Ali Reza Ahmadi, UK Power Networks and Dr Biljana Stojkovska, National Grid, presenting on Power Potential at the Future Networks Conference, with examples of supporting social media coverage on LinkedIn**



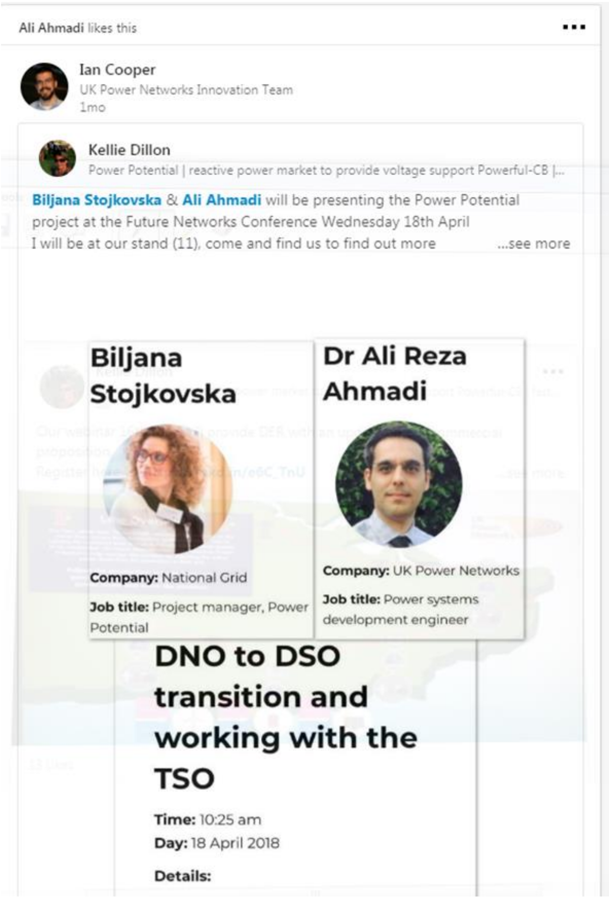
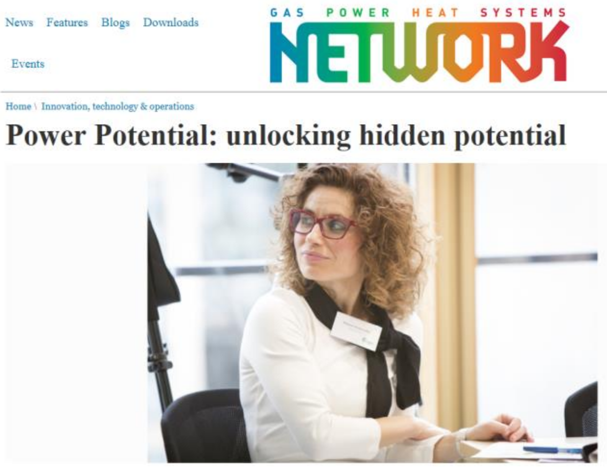


Figure 13: Editorial coverage in the online Network Magazine, March 2018




## 4.6 Conclusion

This chapter has presented an insight into the engagement and recruitment process being undertaken by the project team to ensure there is sufficient participation in the Power Potential project to achieve the project objectives. Through the ongoing regular and targeted activities to engage and secure commitment from DER within the area, we continue to work towards the target of having at minimum 10 trial participants able to create a competitive market and deliver a service with an impact at the GSP level during the trial period.

## 5. Tendering approach, technical and commercial requirements for participation

This section explains the tendering approach, technical and commercial requirements for Power Potential. Following feedback from interested project participants and the Regional Market Advisory Panel, to achieve the project's objectives the reactive service component of the Power Potential trial was split into three 'waves'.

- Wave 1 is predominantly aiming to trial the technical aspects of the Power Potential services, and through the trial allow participants to recover most of their costs. Wave 1 includes a mandatory technical trial, which must be completed before a DER can participate in the optional technical trial. The optional technical trial is split into two time blocks to allow technical trials during winter and summer.
- Wave 2 introduces competitive bidding between DERs, with the volumes accepted by National Grid shaped by reference to the actual market need and assessed against the transmission reinforcement counterfactual. Although volumes procured will not be used to secure the system.
- Wave 3 brings DERs into competition with traditional options currently available to National Grid. Only DERs that are more cost-effective than those alternatives will be accepted. National Grid is entitled to secure the system using DER's services during this wave.

For the active service, DERs must complete a mandatory technical trial first. Afterwards they can start competitively bidding to offer active power to the TSO. This chapter focuses on the primary commercial framework designed for the services and how it was derived through consulting interested DERs. This will be trialled through waves 2 and 3 for the reactive service, and through competitive bidding for the active service. These details were discussed in SDRC 9.2, and have been developed since its publication. More details on the trial design and details of each wave and the consultative approach taken to finalise this design is discussed in chapter 7.

### 5.1 Tendering horizon and payment structure

A fundamental principle of the project is that the services will be procured through a market-based solution. This is because the project team believe that market based solutions provide the best outcome for consumers. As such, DERs will be paid based on the bids they submit in the tender, as opposed to receiving a pre-agreed price. DERs enter their chosen price into the tender – either daily or less frequently, depending on how active the participants wish to be – and will compete with other DERs in the area (during wave 2), as well as transmission-connected assets (during wave 3), to deliver an effective service. During wave 3, National Grid intends to accept bids that represent a lower cost than alternative actions that could be taken to solve voltage issues. The intention is that this will support a smooth transition from trial to business as usual, to encourage business cases to be developed on the representative value of services.

As can be seen from the existing Balancing Mechanism and Ancillary Balancing Services, there are a range of payment structures that could be applied to the project.

Two aspects were considered when determining the most suitable approach:

- Tender horizon: some tendering arrangements, such as the capacity market, allow DERs to secure contracts ahead of time and for up to several years at a time. The contrasting position would be to procure closer to real-time, offering shorter term contracts awarded shortly before delivery would commence. This would accommodate the variability in the production of some new DER technologies.
- Payment basis: typically, DERs can be paid based on utilisation (the MWh or Mvarh they produce) and/or on availability (being in a state of readiness to deliver MWh or Mvarh for a period). Payments can also be made based on capability (reflecting an asset's ability to maintain the capacity to deliver a service, even if it is not available to provide it). There are also degrees between these classifications, such as nomination or arming payments, which typically refer to a fee in addition to, or in lieu of, the availability payment paid only if a DER is placed into a state of readiness.

The range of combinations of horizons and payment bases that were considered were set out in SDRC 9.2. A proposition that included both payments for availability and utilisation, with availability secured at the day-ahead stage, was identified as the most appropriate solution for several reasons including:

- This approach aligns with the principles underpinning National Grid's product simplification developments.
- Availability payments provide a more attractive proposition to DERs than utilisation alone and increase confidence in the revenue potential and therefore participation.
- National Grid and UK Power Networks can secure volume ahead of utilisation timescales, as availability payment for being ready for service delivery places an element of commitment on all parties involved but without committing consumers to full costs.

It was noted by some stakeholders that not offering longer-term contracts will be a challenge either to secure approval to undertake site works, or to engage potential participants or customers (particularly in the case of aggregators). It is believed that participation by assets should be feasible where there is little or no change required to their systems, or where the information on possible utilisation of services provides sufficient reassurance to encourage participation. This challenge was a key consideration in the trials design and the use of a fixed fee for participation in wave 1 of the trial was intended to overcome this issue i.e. by offering 'fixed fee for a fixed number of hours, this lowered uncertainty to trial participants by guaranteeing firm revenue, whilst securing technical data for the project. More detail on this is provided in chapter 7 on trials design.

Table 6 sets out the high-level terms for the Power Potential services. This was shared with DERs prior to drafting up Power Potential Framework Agreements to seek feedback. This shows that participants will receive an availability payment for making the reactive service available across a service window and this will be paid on a £/Mvar/h basis. The reactive service also includes a utilisation payment to be based on £/Mvarh instructed and delivered. The rationale for this was that it allows DERs to offer availability, providing them financial certainty required to invest in the necessary equipment to participate in the trial. This approach is also in line with other balancing services where the TSO values having providers in a state of readiness and able to deliver a service quickly (within seconds) to respond to a system need.

For the active power service, these DERs are not expected to incur system upgrade costs for the provision of this service and this logic does not apply and so the active power service will only be made up of a utilisation payment based on £/MWh instructed and delivered.

As with other balancing services provided to the transmission system, penalties will be applied in situations where delivered services do not meet the procured levels to help ensure the power system stays within stable operating parameters. These penalties entail a reduction in availability and/or utilisation payments made to providers, as established in each service contract, rather than a fine or charge being paid by the provider. To maximise learning from the trial, more lenient performance factors of 80% are being put in place. This is intended to alleviate some of the apprehension experienced by participants in unknown markets and offers more comfort and room for learning than simply applying the performance factors currently in place for existing and established services such as Firm Frequency Response (95%).

Table 6: Draft heads of terms

| Contract Aspect | Reactive Power (Mvars) | Active Power (MWs) |
|---|---|---|
| **Availability payments** | Where a service is procured from DERs, availability payments will start from the beginning of the contracted period, i.e. £/Mvar/h. | There will be no availability payment for the active power service. |
| **Utilisation payment** | Payments to be based on £/Mvarh instructed and delivered at POC | Payments to be based on £/MWh for the MWh instructed and delivered. |
| **Prequalification & testing** | Interested parties must complete and submit the Technical Characteristics Submission Spreadsheet. UK Power Networks will outline any testing and monitoring requirements as a condition of participation in the trial. Reactive service providers should be able to automatically deliver changes in reactive power capability in response to system voltage changes. Active power service providers must be able to provide the service for a minimum of 30 minutes. | |
| **Penalties** | During the trial, for reactive power services availability payments will be scaled back in any given settlement period (a month) if delivery is less than 80% against the service instructed. The availability payment will be scaled back by the corresponding percentage of service undelivered. | |

## 5.2 Feedback on the Heads of Terms

Table 6 above was published to interested trial participants in a webinar in January. We asked DERs to submit a *Technical Characteristics Submission Spreadsheet*. The spreadsheet was produced by the project team and was accompanied by a guidance document to help complete it. The information submitted by DERs in their TCSS has been processed to determine the capabilities of the generators to provide services under Power Potential and to identify any possible technical limitations.

Figure 14 shows the timeline of activity we undertook to seek feedback on the commercial proposition. Running this exercise with interested participants allowed us to take feedback on board as we shaped the commercial framework. It also informed us of the areas where we needed to provide more detail during our engagement with them as we designed our final proposition. A summary of this feedback and how we acted on this is captured in table 7.

**Figure 14: Timeline to reflect how engagement with DERs and the Regional Market Advisory Panel shaped the Power Potential Commercial Framework**

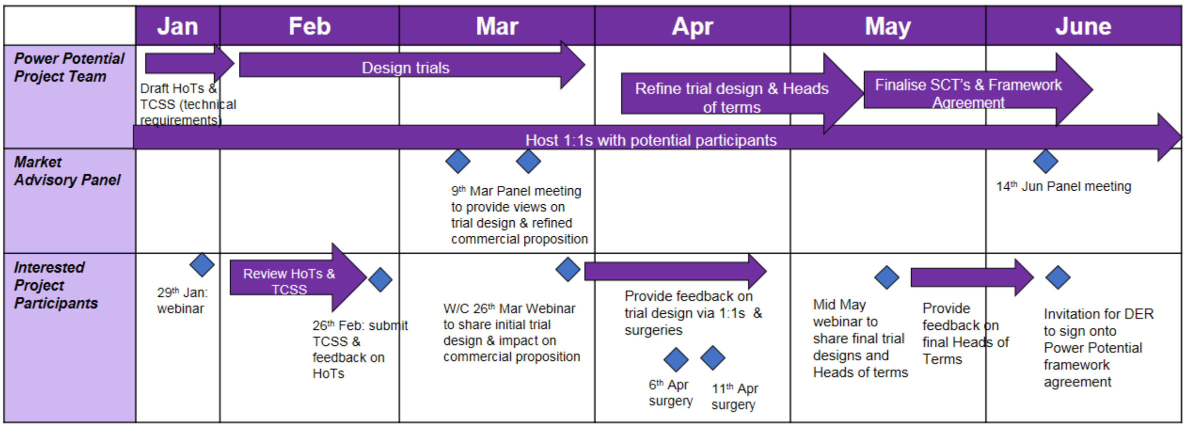



**Table 7: DER's feedback and the approach the project team has taken as a result**

| DERs said…. | We did… |
|---|---|
| We welcome day ahead procurement | Power Potential will trial the procurement of services via day ahead auctions. |
| We need further clarity on technical aspects of the project:<br>▪ Prequalification, testing and metering requirements<br>▪ How often will instructions be sent? | A combination of updates via webinars, addressing queries directly with DERs in one-to-ones as well as publishing documents allowed us to address technical queries. Table 8 outlines the documents we published, their purpose, along with a link to each document. Figure 15 and Tables 9, 10 and 11 show the information shared with DERs in webinars to address specific queries. |
| We need further clarity on commercial aspects of the project:<br>▪ Interaction with the provision of other balancing services<br>▪ Need to recover costs related to the participation – to avoid incurring losses in the trial | |

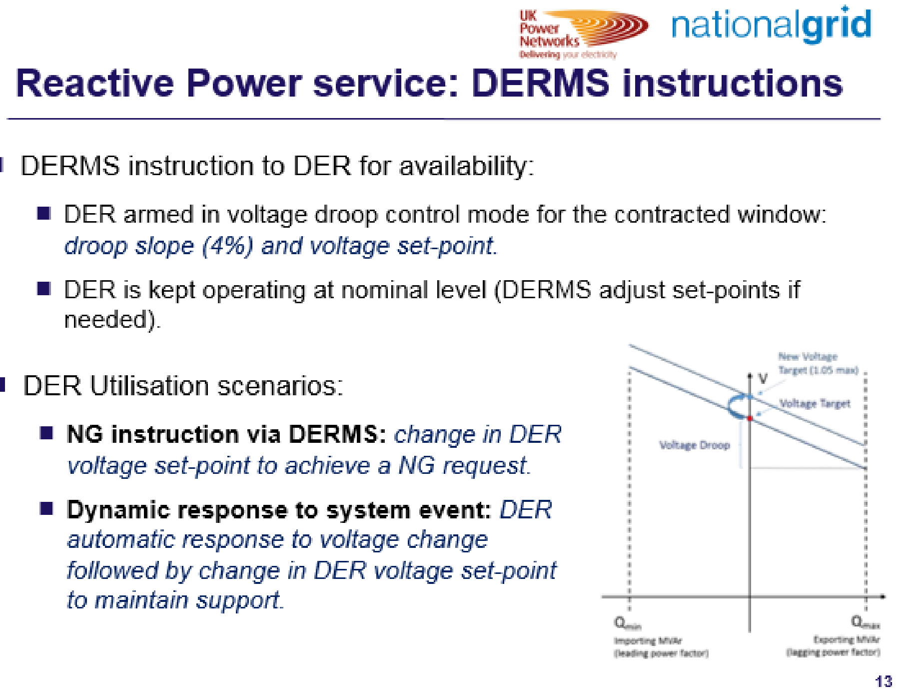
**Table 8: Key published documents for potential participants**

| Document | Purpose |
|---|---|
| **A guide to participating** | An overview of the aims of the project and criteria to participate.<br><br>Link: Document.<br><br>Note: In addition to the hyperlinks in this table, the full web address to download all documents is provided as a footnote[6]. |
| **Heads of Terms** | Contractual structure and key terms<br><br>Link: Document |
| **Technical Characteristics Submission Spreadsheet** | To capture generator specifications and potential outputs<br><br>Link: Spreadsheet. |
| **DER technical requirements** | Our communication protocol and how to integrate with DERMS and overview of testing<br>Link: Technical guidance document. **Document.**<br>And<br>Link: DER Technical Requirements for participating Distributed Energy Resources. **File.** |
| **Provider Framework Agreement** | Contract to allow participation<br><br>Link: **Document.** |
| **Market Procedures** | How the market will operate<br><br>Link: **Document.** |

In our March webinar[7], we addressed the feedback given on the *Heads of Terms* document. To address queries relating to prequalification, testing and metering requirements we published the *DER Technical Requirements document*. Figure 15 (on the following page) was used in our March webinar to clarify to DERs the frequency of instruction.

[6] www.nationalgrid.com/powerpotential
[7] Webinar slides

**Figure 15: To address the DER query regarding frequency of instructions**




### 5.2.1 Provision of multiple services

A common query from potential participants is whether Power Potential products can be co-provided with other services at the same time. Where possible, we wish to encourage participants to deliver both the reactive and active Power Potential services. Table 9 was presented in March's webinar to clarify to DERs whether Power Potential products can be provided alongside other services at the same time. For reactive power provision under Power Potential, our position is that this can be provided in conjunction with a National Grid active power balancing service, if the existing balancing service is not compromised. This is not the case for active power provision under Power Potential in conjunction with another balancing service. As the provision of a service such as STOR or FFR would negate the curtailment action needs of Power Potential. To maximise learning in the project, we are allowing providers to offer active power services under Power Potential outside of any period where the plant is contracted to deliver an active power balancing service to National Grid.

For flexibility services to UK Power Networks, the service of reactive and active power can be provided if the flexibility service which would require generation turn up, i.e. the provision of active power or demand turn down is not compromised, by the provision of reactive power services under Power Potential. However, optimisation will aim to maximise both services. In relation to DERs with non-firm connections, the project encourages these DERs to participate in the trials. This is due to the compatibility of the Power Potential project with the framework around non-firm connections. More specifically, under the active power service of Power Potential, the project is likely to request a reduction in active power, which is in line with the service under Active Network Management (ANM).

Table 9: To address queries on the interaction of Power Potential with other flexibility and balancing services

## Provision of multiple services

| Other service | Reactive Power (MVArs) | | | Active Power (MWs) |
|---|---|---|---|---|
| **National Grid's Balancing Services (MWs)** | ● | Provision of both Balancing Service and a reactive power service is possible, provided the performance of the existing Balancing Service is not compromised, e.g. by curtailing MW availability to provide MVArs | ▲ | Provision of both services **simultaneously** is **not** possible as the services would counteract each other. Conditional provision i.e. outside of any period where the plant is contracted to provide National Grid Balancing Services is possible. |
| | Can I Participate? | | | |
| **Firm Frequency Response** | ● | Yes | ▲ | Yes – Conditional outside of any period where the plant is contracted to provide FFR |
| **Short Term Operating Reserve** | ● | Yes | ▲ | Yes – Conditional outside of any period where the plant is contracted to provide STOR |
| **Demand Turn Up** | ● | Yes | ▲ | Yes – Conditional outside of any period where the plant is contracted to provide the DTU service |
| **Capacity Market Contract** | ● | Yes | ▲ | Tbc – the service is not classed as a relevant balancing service and penalties could apply under CM rules |
| **Flexibility services to UKPN** | ▲ | Yes – Conditional if Q reduces by change in active power | ▲ | Yes – Conditional if there is conflict of simultaneous signals regarding active power output |
| **Non-Firm Connections** | ● | Non–firm embedded providers will be allowed to participate in the Power Potential trial. Under the active service the project is likely to be requesting a reduction in active power which is in line with services under ANM. | | |

### 5.2.2 Feedback form Regional Market Advisory Panel

Clarifying the approach to provide of multiple services was discussed with the Regional Market Advisory Panel in March. It was clear that stakeholders across industry felt it is important that prospective service providers can access multiple, complementary markets to maximise the value of their assets. This is aligned with the Energy Networks Association's Open Networks Project[8], National Grid's overarching strategy of facilitating broader market development and UK Power Networks' DSO[9] and flexibility strategies. Given we can explore this within an innovation project, our approach is to enable the provision of multiple services as much as possible to provide learning to industry. This is outlined further in chapter 7.

8 http://www.energynetworks.org/electricity/futures/open-networks-project/

9 futuresmart.ukpowernetworks.co.uk

## 5.3 Payment agreements

### 5.3.1 Window definitions

Active power service will be procured in line with operational needs, in 4-hourly EFA (Electricity Forward Agreement) blocks, where possible in line with feedback from DERs as illustrated in Table 10. This is because the nature of the active power service is that the requirement will vary depending on real time system needs. It is critical the TSO has options. Feedback from some DERs suggested that the ability to submit bids in EFA blocks aligns with other markets they may be participating in so this would seem an optimal approach to take for the Power Potential service. This is also a development that is reflected in other established ancillary services markets (e.g. Firm Frequency Response) at National Grid.

Table 10: The Four-hourly Electricity Forward Agreement blocks

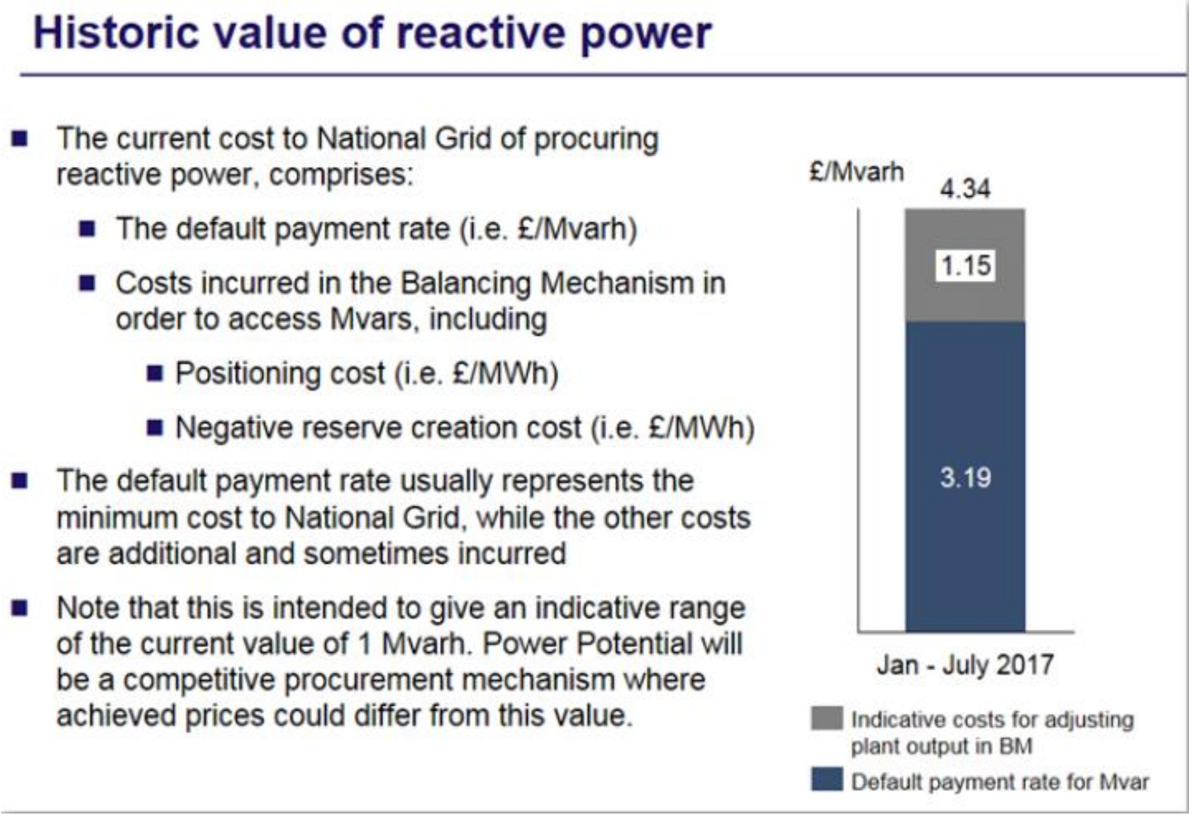
| Four-hourly periods (Greenwich Mean Time) |
|---|
| 23:00 – 03:00 |
| 03:00 – 07:00 |
| 07:00 – 11:00 |
| 11:00 – 15:00 |
| 15:00 – 19:00 |
| 19:00 – 23:00 |

## 5.4 Market value of reactive power service

Feedback from DERs indicated further guidance was required on the value of reactive power within the project area, and the project will work to provide further information on historic costs, consistent with National Grid's work on transparency and its *Reactive Roadmap*.

Reactive power requirements are currently met by transmission connected generators through the mandatory reactive power scheme, with little to no participation in the commercial reactive power market. The cost of procuring reactive power through this route comprises the default payment – standard across all generators – and a positioning cost, if a generator's active power output must be adjusted to deliver the reactive power. The average price paid for this service between January and July 2017 (£4.34/Mvarh) was presented to DERs as an indication of the historic price of reactive power in the project area in the September 2017 webinar (see Figure 16). This average figure should not be interpreted as a guaranteed price for the Power Potential trial, or possible maximum or minimum payments. They are presented as an illustration of historic value, to be used as a starting point for cost-benefit analysis, but recognising that bids from DERs would be compared against the marginal transmission alternative rather than the average.

Figure 16: The January to July 2017 average price for reactive power presented at the project's September 2017 webinar




As outlined in National Grid's reactive roadmap the requirement for reactive power absorption has consistently increased for the last 10 years. National Grid's forecasts show this will continue. The reasons for this, and the actions on National Grid to ensure we can take economic actions to manage this are set out in the *Reactive Roadmap*[10]

Details of the future reactive requirement can be found in *National Grid's 2016 System Operability Framework*. Page 137, figure 4.28, figure 4.29 and figure 4.30 of the document describe the zonal maximum reactive power requirement by region in 2016/17, 2020/21 slow progression and 2020/21 consumer power. The results show the total post-fault reactive power requirement, inclusive of voltage regulation. The requirements for post-fault containment and recovery increase over the period as the support available from synchronous generation declines.

[10] Product Roadmap

## 5.5 Addressing common queries in May's webinar

**Table 11 - Common queries from DER and the project team's resulting actions**

| DERs said…. | We did… |
|---|---|
| Can my power factor range be extended beyond that prescribed in my connection agreement, to enable me to offer larger volumes of reactive power? | Decisions shared in our webinar in May:<br>• power factor ranges can be extended based on the Power Flow studies undertaken and subject to DER acceptance (connection agreements would then need to be amended to reflect this for the duration of trial)<br>• Decision not to apply additional DUoS charges to DERs delivering Power Potential services during the trial, but to record what happens for project learning & consideration for future application |
| How will participating in the Power Potential project impact on my Distribution Use of Service (DUoS) charges? | |

### 5.5.1 Impact of power factor ranges on DER's reactive power capability

Power factor studies were carried out for each site that provided a *Technical Characteristics Submission Spreadsheet* and is energised.

The goal was to understand whether each DER's power factor range could be extended beyond prescribed in their connection agreement (typically 0.95 lead and lag) so that they could bid larger volumes of reactive power. One of the examples where it might be valuable is for a PV farm, which at night has all its rated capacity available (it is equivalent to power factor equal zero).

A methodology was developed to perform the studies. These were carried out for defined scenarios using several assumptions. These, along with the detailed results will be shared with each DER. The overview of the objective of the study's methodology, scenarios and assumptions, along with the findings is presented in Appendix C.

## 5.6 Consultation on draft framework agreement

Draft terms of the DER-UK Power Networks framework agreement were shared with all interested participants and published on the project website with a draft market procedure document outlining how the Power Potential market would function in 2019. This exercise was used to inform the final commercial proposition, together with feedback received in DER meetings and via the Regional Market Advisory Panel. Respondents to the consultation were asked to answer the following questions:

1. *What are your views on the contractual terms required to participate in Power Potential?*

2. *What are your views on the proposed Power Potential payment structure?*

3. *What would an appropriate £/MWh payment be for the mandatory technical trials for the active power service?*

4. *Any further comments you would like to express?*

The table below summarises the responses from this consultation and how we used the feedback to finalise the commercial proposition. Appendix D shows the complete responses received from the formal consultation.

**Table 12: Summary of feedback from formal consultation of draft framework agreement and market procedure and project responses**

| Common feedback from consultation | Project response to progress feedback |
|---|---|
| Further clarity sought on how DERs will be judged 'available' | Updated definition of 'available' in market procedure and framework agreement to make this explicit |
| Will the maximum payment be revised up to cover a greater proportion of costs, as £20,000 is considerably less than costs now understood following detailed scoping? | This was considered in the finalised commercial proposition and an increased participation payment offered. |
| Could you provide an indication to the total value of this market i.e. budget assigned to service payments? This will help us understand the potential revenue that could be received in this part of the trial. | Budget for each wave confirmed in market procedure document. |
| Can you provide information for what price level would be considered competitive by National Grid including the costs associated with derating active power or maintaining generation out of merit? This will help make a forecast of any expected future revenues. | Re-circulated analysis relating to historic price of reactive power (as described in chapter 5.3 of this document). |
| We anticipate providing reactive power during periods when there is no active power generation from the solar sites (Q at night). To calculate Availability Thresholds will de-rating be based on a baseline of 24 hours per day or a baseline of declared day-ahead availability? | Availability thresholds relaxed slightly with wave 1 period extended to allow greater opportunity for DERs to hit the thresholds. |
| An appropriate £/MWh payment for the mandatory technical trials for the active power service would compensate for loss of renewable certificate revenue and exposure to imbalance charges as a minimum. | The £/MWH payment was determined with a view to compensate for loss of revenue and exposure to imbalance charges. |
| Generator Distribution Use of System (DuoS) exceedance exposure charges during wave 1 should be explicitly defined as being recoverable as earlier communicated. | Market procedure updated to make this explicit. |
| Lack of utilisation payment for wave 1 makes it less attractive to make entire MVAR range available. | An increased availability payment is in place to help overcome this hurdle. As effectiveness of service delivery will be deduced during wave 1 no utilisation fee will be paid, though utilisation is anticipated to be low during these hours. |

## 5.7 Market Reporting

The Power Potential project may use all technical and market data for the purposes of assessing the progress of the trial. The intention is to provide some level of market reporting on the outcomes of the tendering process. This should help to inform DER's bidding activities. The level of detail is yet to be determined but will need to consider:

- The need to anonymise commercially sensitive data
- The desire to be transparent about the procurement of system services
- The need to avoid facilitating anti-competitive bidding practices.

The form of market reporting will be discussed with market participants before reporting commences.

# 6. Commercial framework and interaction with SO and DNO incentives

## 6.1 Introduction

The final commercial framework for the project and the proposition has been presented to DERs. Throughout autumn 2017, the project team engaged with several interested parties to promote the opportunities available and seek feedback to shape the commercial arrangements of the project, as described in chapter 3.

Progress has been made in understanding the perspectives of owners and aggregators of different DER types, defining a greater level of detail for the commercial proposition, establishing and communicating the historic price of reactive power service, establishing commercial requirements for DERMS, and working with academic partners.

The next phase of the project will focus on moving the finalised framework into implementation – contracting with interested DERs and continuing to recruit additional volume to maximise learnings from this innovative revenue stream.

## 6.2 Insight from Cambridge University to develop the market framework for the reactive power service

As Power Potential is believed to be a world first project, there are many variables we would need to consider when developing the commercial framework. To support this, we sought the input of Cambridge University, who have published the Reactive Power Management and Procurement Mechanisms: Lessons for the Power Potential Project report. The report looks at the international experience in the management and procurement of reactive power to identify specific lessons for the Power Potential project. Two specific case studies discussed in the report relate to the use of competitive mechanisms for the procurement of (1) reactive power in Australia (business as usual, NSCAS) and (2) demand response services in California (a pilot project, DRAM).

Section 6 in the document highlights many issues raised by the study of procurement mechanism design for the Power Potential project. They can be summarised as presented in Table 13.

Table 13: Cambridge University recommendations and the Power Potential approach adopted

| Auction Mechanism Variable | Cambridge Recommendation | Power Potential Approach |
|---|---|---|
| **Trial participation and encouraging new entrants.** | In the future, DERs participation should depend on whether it can compete (in terms of prices) with transmission connected resources or other future options. | Power Potential trials are structured into a series of waves (see section 7). The wave 2 auction design encourages new entries (i.e. DERs) and more market participants in the supply of reactive power services (DERs plus transmission connected resources). Wave 3 of the trial will assess DERs in line with transmission alternatives to test if DERs can compete with such resources. |
| **Enhancing competition between DERs across the four GSPs via a package auction design.** | A joint auction allows a higher combination of products enhancing competition via substitution between reactive power suppliers. This would be a more complex auction design than the one proposed by Power Potential, however total procurement cost could be lower by selecting the combinations that maximise social welfare (similar to the use of co-optimisation in the USA). | For simplicity of the trial and assessment of bids, DERs will be allocated to the GSP it is most effective at and auctions ran between DERs at each GSP. A manual joint auction will be trialled for project learning and would be a key consideration when assessing the results of the trial. |
| **Pay as clear or pay as bid auction and consideration of a quality dimension.** | Consideration of pay-as-clear price. In economic theory, a second-price auction would work better for true price discovery with higher dynamic efficiency in comparison with pay-as-bid. The consideration of quality dimensions in the procurement process (represented by the locational effectiveness of reactive power) should be a part of good auction design. | A key design principle for the Power Potential services was to align with existing balancing services. For that reason, as pay-as-bid is an approach that is well-known by National Grid and market participants it is the mechanism that will be used for the trial.<br>Locational effectiveness will be used as a quality dimension to assess bids. |

| Auction Mechanism Variable | Cambridge Recommendation | Power Potential Approach |
|---|---|---|
| **Non-delivery penalties and pricing format (availability + utilisation).** | Due to the new requirements for DERs (as a result of implementing European Codes), reactive capability is going to be compulsory. This implies only a utilisation payment is necessary. This is something that would need to be taken into account when contemplating the large-scale implementation of Power Potential. | The proposed non-delivery penalty under Power Potential affects the availability payment only, though utilisation will only be paid on delivery of Mvar as instructed. Use of an availability payment for Power Potential trials is to provide incentive to DERs who do not currently have the capability to provide the service to invest in order to participate and have the opportunity to recover their costs. As all new DERs will be mandated to have this capability we agree that there is a need to reassess the appropriateness of an availability payment following the trial when considering a rollout of the services as business as usual. |
| **The frequency and periodicity of the auction and the cost benefit of nearer to real time procurement and co-optimisation.** | More frequent auctions allow both parts (suppliers and system operators) to adjust the reactive power offers and prices in nearly real time (day ahead in Power Potential). Shorter trading periods can help to reduce balancing service costs by allowing similar trading periods for each ancillary service and the energy market. This practice is referred to as co-optimisation and may result in important system costing savings. | Use of day ahead auctions will allow more economic procurement as requirements will be better understood the closer to real time the procurement takes place. This will be a key learning point for the project, particularly regarding how active DERs are when given the opportunity to bid daily. This approach aligns with the direction National Grid is taking with ancillary services markets. |
| **The careful specification of the counterfactual against which the auction results are to be evaluated.** | Reactive power can be acquired through auctions but also via transmission or distribution reactive equipment or through other future options (identifying and despatching of a specific DER using a similar approach to the current mandatory mechanism, offering a fixed price to DERs for reactive power). Running a reactive power auction mechanism for a small number of GSPs could be costly. | The counterfactual that DER bids will be assessed against to prove the commercial viability of Power Potential is the avoided cost of transmission reinforcement i.e. not needing to build/install transmission equipment for reactive compensation due to being able to manage voltage through market mechanisms. A cost benefit analysis of this will be undertaken by Cambridge University to inform the value of the approach and savings to the end consumer. |

| Auction Mechanism Variable | Cambridge Recommendation | Power Potential Approach |
|---|---|---|
| **Contract design between the TSO and DSO.** | The contract between the DSO and TSO should incentivise optimal risk sharing. Under Power Potential, the DSO assumes a new role that may expose it to a significant energy price risk (unlike now). Suitable contractual agreements are required in order to incentivise DSOs to optimise their provision of reactive power (and other ancillary services). | During the trial, risk is managed by the project, however this will be a key learning point for the project and options to address this will be explored in SDRC 9.7, one of the final deliverables of the project. |

### 6.2.1 Lessons to Power Potential from the two case studies

Table 14: Recommendations from Cambridge University's two case studies and the Power Potential approach

| Lesson | Cambridge Recommendation | Power Potential Approach |
|---|---|---|
| **About the products** | It is important to know about other products that DERs providers are currently offering to National Grid or to other parties. There are products that can be mutually exclusive. This is in line with the clarifications made in DRAM (Demand Response Auction Mechanism) where offers are not allowed to be part of DRAM and of other Investor Owned Utilities demand response programmes simultaneously. | For the project trial, the product is limited to reactive and active power services only. It means that other potential products are not considered in the evaluation of the offer (DERs compete only for the products specified in Power Potential). More detail on provision of multiple services is covered in 5.1.1. |

| Lesson | Cambridge Recommendation | Power Potential Approach |
| --- | --- | --- |
| **About the products** | The project may benefit more from resources that are able to operate outside the mandatory range (0.95 PF). Lower power factors mean an increase in reactive power export/import but a decrease in active power. Power Potential has ruled out curtailing MWs of DER in order to increase MVar (on the assumption that the value of MVarh will be significantly below that of MWh). This would be in agreement with the Australian Energy Market Operator (AEMO) in the procurement of Network Support and Control Ancillary Services (Australia), where reactive power services are required in excess of the performance standard for reactive power. | A capability of 0.95 power factor is required in Power Potential in line with DER connection agreements. This is in line with Grid Code requirements for Transmission connected generators. UK Power Networks has identified wider power factor range as a potential for DERs to offer larger reactive power volumes and carried out studies to establish where the DER's power factor operational range can be extended beyond their connection agreement limits.<br>For the purposes of the project, Power Potential has ruled out curtailing MWs of DERs in order to increase MVar (on the assumption that the value of MVarh will be significantly below that of MWh). |
| **Participation criteria and eligibility** | DERs need to be clear about the extra costs to be incurred (such as control and communication costs) to participate in the project trial. A way to mitigate the capital costs is offering an incentive to DERs in the form of a fixed rate regardless of the size of the DERs (wave 1), that would amount to £25k (based on the control and communication equipment average costs). Taking into consideration that this is the first pilot project that seeks to procure reactive power services from DERs in a limited area (initially four GSPs) and that auction theory suggests increasing the number of participants is important, we think this is a reasonable strategy. In the case of DRAM, bidders are allowed to include all 'peripheral costs' associated with the service in the contract price they offer, including those relating to scheduling coordinator costs. However, bidders are responsible for all costs related to connection rules (Rule 21) and the same applies in the NSCAS tenders in Australia. This makes sense in these two cases because demand response is a more contestable product than reactive power (from DERs) and NSCAS is now a business as usual tender for reactive power services. | Wave 1 offers DERs some certainty in cost recovery by paying a fixed fee for a fixed number of hours of participation. |

| Lesson | Cambridge Recommendation | Power Potential Approach |
|---|---|---|
| **Participation criteria and eligibility** | DERs need to know the reactive power capacity to be procured at each GSP to be estimated by National Grid. Aggregators and individual DERs need to evaluate the best portfolio of offers that would work for them. | At our webinar in May, we shared with DERs that the holding volume for Power Potential auctions will be between 10-50 MVARs across all of the GSPs (actual availability volumes will be determined at day ahead in line with system needs), as well as publishing daily utilisation volumes on 1 Mvar of availability (based on averaged data collected April 2016 – April 2018) for the trial region[11]. This data is not intended to be a forecast of utilisation requirements in 2019 as it is uncertain how utilisation will turn out; actual utilisation during trials in 2019 will be in line with real time operational requirements, but to support DERs in assessing their participation in the trial. |
| | There are still some items of information about the auction mechanism that are unclear: periodicity (up to 12 months assuming a start in January 2019 or less than 12 months if budget is insufficient); the way in which National Grid will value the two kinds of payments and whether there will be a cap on the maximum offer payable (if applicable and in agreement with the capacity cost cap set in DRAM); the value of reactive power services on different days and in different time windows (reactive power services at night time may be more valuable than at day time on weekdays). | Wave 1 up to 1,850 hours, wave 2 minimum of 1,800 hours, wave 3 in line with system needs. Wave 2 bids will be assessed against the transmission reinforcement counterfactual and wave 3 will assess bids in line with alternative actions available from transmission connected generators. |
| **Evaluation criteria** | The evaluation criteria need to be clear. A good example is observed in the DRAM Request for Offers. The methodology is comprehensively explained and is complemented by spreadsheets (with random values) that bidders can download from the Investor Owned Utility's websites. In the NSCAS tenders the methodology is not clear (and it is not clear would happen if there were any ERPS offers in GB). | High-level assessment principles are included in the published Power Potential Market Procedures document[12]. |

[11] Historic Utilisation Charts

[12] Power Potential market procedures

| Lesson | Cambridge Recommendation | Power Potential Approach |
|---|---|---|
| **Evaluation criteria** | The use of non-cost variables has not been considered in the evaluation of the DERs in Power Potential. The scoring matrix from DRAM sets a good reference for the identification of non-variable costs that can minimise the risk of having DERs with poor deliveries and can favour particular sources of reactive power (such as residential reactive power). | Non-cost variables have not yet been considered for simplicity, however we remain open to reviewing this following the trial as we assess our learning. |
| | The locational effectiveness of reactive power equipment plays an important role in the evaluation. AEMO provides maps not only with the areas that have the highest locational effectiveness but also with additional information about the transmission network (substations, transmission lines at different voltages, etc.). National Grid is also providing effectiveness heatmaps for each GSP however DERs may benefit from doing a better evaluation of its options if additional information can be provided, drawing on AEMO's experience. | Heatmaps have been provided to DERs to show areas of greater or lesser effectiveness. During one-to=one meetings with DERs, their own effectiveness has been communicated to them. As much data as possible has been shared without compromising commercial confidentiality. |

In summary, the Cambridge University report states:

*"The PP project seeks to be novel and trial new ways of procuring RP. Our discussion of the principles of mechanism design would suggest that attention to the following: the frequency of the auction and its price resolution offers significant scope for learning on what sort of price resolution might be necessary/desirable or possible; consideration of the use of pay-as-clear (rather than pay-as-bid) to reveal information about underlying costs and to experiment with a different (and arguably superior) payment rule; and more consideration of how to enhance substitutability of products within the trial area, particularly by integrating the procurement across the 4 GSPs."*

## 6.3 Interaction with SO and DNO incentives

### 6.3.1 Interaction with the GB System Operator's Incentive Framework

The project will help enable more customers to connect in the south-east region in Great Britain. It will also defer network reinforcement needs in the transmission system creating consumer value. The Power Potential bid estimated that these benefits translate into the following savings in the longer term:

- 3,720 MW of additional generation in the trial region by 2050.
- Savings of £412m for consumers by 2050 if rolled out across GB.

For the period 2018-2021 the Electricity System Operator (ESO) has agreed a new three year incentives regime with Ofgem, which will be in place during the project trial period. In accordance with Ofgem's incentives guidance, initiatives which are funded under RIIO-T1 innovation schemes should be discounted from ESO incentive performance, unless it is clear that the ESO has gone above and beyond simply delivering the initiative in order to achieve additional consumer value (taking into account the funding amount). Hence it is our interpretation that this is how Power Potential will be treated with respect to the ESO's 2018-2021 incentives performance.

#### 6.3.2 Interaction with DNO incentives and obligations

The Power Potential project takes place during the RIIO-ED1 price control period. The price control incentivises UK Power Networks to improve the service it provides to its customers in specific output areas, as Reliability & Availability, Connections and the Environment[13]. UK Power Networks ensures that while undertaking the Power Potential project it does not have any material impact on the incentives in relation to the above output areas. For example, UK Power Networks notes that the Interruptions Incentive Scheme (IIS) is not affected. Also, for other incentives, such as the Time to Connect, the Power Potential project has no impact as the participating DERs are already connected to its networks. The project provides UK Power Networks with the funding required to:

- Develop the technical solution including the distributed energy resources management system.
- Compensate distributed energy resources for their service during the trials' phase, such as for their output of reactive power at their point of connection to UK Power Networks' network.

In the current context of RIIO-ED1, UK Power Networks is required to promote/not distort competition in the generation or supply of electricity through:

- The relevant legislation, Section 9(1) of the Electricity Act 1989 (as amended).
- Condition 4 of the distribution licence.

As the project will establish a competitive market environment for reactive power at the distribution level, it actively promotes the competition in generation or supply of electricity.
Furthermore, the project demonstrates UK Power Networks' transition from a DNO to DSO model. More specifically, it facilitates the development of a practical technical and commercial solution to use DER's flexibility for the DNO and GB's System Operator.

It is expected that some of the lessons to emerge from the trial will relate to the RIIO-ED-1 regulatory framework and will also help inform the RIIO2 framework. Hence, these will inform improvements and modifications that may enable the DNO to operate more effectively or at a lower cost to consumers. It is assumed that such changes would not be made within the trials' timescales, and would be included as recommendations for further work and future roll-out. The project's commercial team will consider any changes and develop change proposals in the long-term to the distribution licence/distribution code that might be required to enable wider rollout of the methods if successful. This will be discussed further in SDRC 9.7.

For example, the opportunity to roll-out the service into business as usual for the TSO would require UK Power Networks to deliver additional outputs during the RIIO-ED1 price control to cooperate with the TSO to deliver whole system outputs. More specifically, UK Power Networks will be able to roll-out voltage services markets across the GSPs in UK Power Networks' area.

Additionally, Ofgem is currently considering the development of the RIIO-2 framework and including a whole system perspective in the price controls. The coordination between the GB

[13] RIIO-ED-1 Report , p. 10.

System Operator and UK Power Networks Distribution System Operator, is providing valuable lessons already of how a DSO will support the whole energy system in the RIIO-2 price control.

Finally, we note the work commenced by Ofgem to develop a new licence condition on whole system which is being progressed with the Open Networks project work stream one.

# 7. Trials approach and methodology

This chapter describes the process the project team undertook to design the Power Potential trials, as well as describing in detail the trials design for each service to the extent this has been progressed. Given the innovation within the project arises from the reactive power service, this is where most the service payment budget for the trials has been allocated, and most the design effort.

This sets out the current view of the project team, and may be updated as further detail of the trial design is developed.

## 7.1 Approach to designing trials

The objectives of the Power Potential trials are to:

- Demonstrate proof of concept.
- Demonstrate proof of market.

In achieving these aims, the trials have been designed in line with the principles presented in table 15.

**Table 15: The principles underpinning the Power Potential trial design**

| Principle | Commentary |
|---|---|
| **Market efficiency** | Including consideration of:<br>• Level of stimulus to DERs to promote participation<br>• Efficient allocation of budget and in line with project budget<br>As an example, the project is seeking to:<br>• Reward the DERs that are most effective<br>• Pay a fair price that reflects the need for investment to provide the service but does not place participants in a significantly beneficial position going forwards |
| **Operational needs** | • Maintain system security by not utilising trial volume to secure system (for the reactive power service, as it is unproven)<br>• Trials to follow operational profile requirements for reactive power |
| **Continuous review of applicability to business as usual** | • To provide projections for future use |

| Principle | Commentary |
|---|---|
| **Adopting a consultative approach** | • Through establishing the Regional Market Advisory Panel led by an independent chair, which has met three times with a focus on the trial design and commercial approach.<br>• Through engaging potential providers via webinars and one to one sessions. For example, through consulting with DERs on the draft *Heads of Terms* document, valuable feedback on trial design was provided including:<br>  ○ DERs keen to ensure CAPEX costs are recovered and no losses incurred in participating in the trial<br>  ○ Indicative CAPEX costs of equipment (hardware and software) and/or communications/control upgrade for interested DERs range from £15k - £500k, (one submission at the extreme, excluding such, the average cost is £25k)<br>  ○ For the active service, ROC subsidised sites expect utilisation payments to cover opportunity cost up to £200/MWh |

## 7.2 Regional Market Advisory Panel

To provide a formal channel for the project to engage and consult with key stakeholder groups, a Regional Market Advisory Panel (RMAP) was established in early 2018. The Panel is overseen by an independent chair, Dame Fiona Woolf, and is made up of representatives across the industry including Ofgem, BEIS, DER, aggregators and their representatives (see table 16). Three panel meetings have taken place to date, providing valuable feedback on the trial design and terms of the commercial framework which the project team have taken on board. Terms of Reference for panel meetings were agreed with members in the first meeting and can be found on the project website[14], along with the meeting minutes from each meeting.

Table 16: Regional Market Advisory panel members

| Role | Panel Member | Representing |
|---|---|---|
| Panel Chair | Dame Fiona Woolf | Chair, Regional Market Advisory Panel and Partner, CMS Cameron McKenna |
| Panel Members | Hanae de Rochefort | Association for Decentralised Energy |
| | Alice Fourrier | BEIS |
| | Alastair Martin | Flexitricity |
| | Andrew Robbins | Innogy |

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

| Role | Panel Member | Representing |
|---|---|---|
| | Ian Larive | Low Carbon |
| | Louise van Rensburg | Ofgem |
| | Alex Howard | Origami Energy |
| | Sammy Blay | Reactive Technologies |
| | Frank Gordon | Renewable Energy Association |
| Representing National Grid | Claire Spedding | Head of Business Development, System Operator |
| Representing UK Power Networks | Sotiris Georgiopoulos | Head of Smart Grid Development |

## 7.3 Active power service design

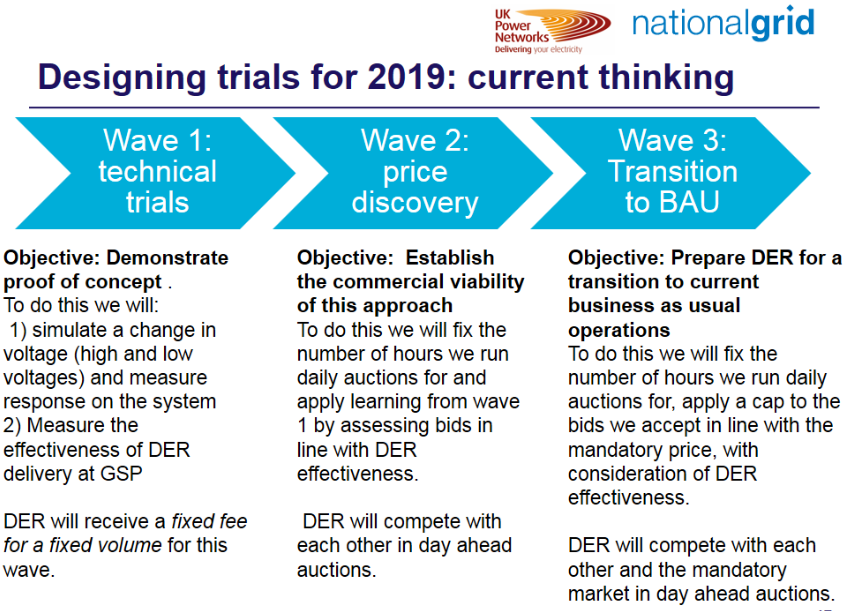
Mandatory technical trials are covered in one single wave to validate the DER's response to an active power set-point instruction before moving to competitive bidding. This case study is to be carried by individual participating DERs and will confirm that DERs working with the DERMS provide the correct response to active power service instructions.  One trial is to be carried out for each DER to trial the response to a MW set-point and this will take place during the first two weeks of the trial. After each DER has successfully responded to this signal, the active power service trials will commence the commercial operation immediately (funded from outside the project budget). To do this we will use our web portal to invite DERs to bid freely to offer utilisation prices for both MW up and MW down services.

These prices will be assessed on a least cost basis and called upon in times of system need to support transmission constraint management. Our minded to position is to ask DERs to submit price volume pairs in EFA blocks as this aligns to other markets they may be trading in. During competitive bidding, DER payments will be made at the level of DER bids (pay-as-bid), and there will be no availability payment for the service.

## 7.4 Reactive power service trial design

The initial trial design developed by the project team was shared with the Regional Market Advisory Panel and with interested DERs via a webinar and is summarised in the illustration in Figure 17.

**Figure 17: Initial trial design shared with RMAP and at DER webinar**




To demonstrate both the technical and commercial Power Potential solution, the high-level trial design splits 2019 into three trial periods (waves) each with a different objective and approach. Each wave is summarised below and described in further detail in section 7.4.

### 7.4.1 Trial wave 1 – initial design

The objective of wave 1 is to demonstrate proof of concept. The Power Potential reactive power service must demonstrate that DERs can deliver both low and high voltage support, in a pre-fault scenario as well as post fault. A key learning outcome for the project is understanding the effectiveness of this support at the Grid Supply Point (GSP). To achieve the objective of wave 1 we will:

- Simulate a change in voltage (high and low voltages) and measure response on the system.
- Measure the effectiveness of DER's delivery at GSPs through controlled service utilisation.

DERs will receive a fixed fee for a fixed volume for this wave. This removes uncertainty to trial participants as it provides a guarantee of some firm revenue, whilst securing technical data for the project partners on DER's ability to deliver the service.

### 7.4.2 Trial wave 2 – initial design

The objective of wave 2 is to establish the commercial viability of the Power Potential service. To do this there will be a fixed number of hours where daily auctions are run and as well as applying learning from wave 1 by assessing bids from DERs to provide the service in line with DER effectiveness. During wave 2 DERs will compete to deliver a fixed volume.

### 7.4.3 Trial wave 3 – initial design

The final wave of the project aims to prepare DERs for a transition to current business as usual operations, where the GB System Operator has other options available (e.g. the mandatory market) and DER must compete with a wider set of options. There will be a fixed number of hours that the daily auctions will run for, applying a cap to the bids that are accepted in line with the mandatory price, with consideration of DER effectiveness.

The trial design assumes that prequalification and testing is completed before trials commence in early 2019.

#### 7.4.4 Regional Market Advisory Panel input to trial design – March 2019

The panel were asked to provide feedback on several questions regarding the trial design and their discussion is summarised below. There was broad support for the waves, with most of the panel arguing that wave 1 should cover CAPEX costs incurred by DERs to upgrade their hardware and/or communications equipment for the trial, as understood by the DERs in early 2018.

A discussion as to how this payment could be made explored several options and the pros and cons to each option were debated amongst the panel with no clear agreement made as to any option.

Table 17: Regional market Advisory Panel discussion on payment options

| Option | Pros | Cons |
|---|---|---|
| Set the fee at the lower end of the CAPEX range incurred by DERs | Consistent for all, which could be considered fair and prevents over compensating | Would be losers |
| Ask participants to go open book and justify their costs, reimbursing actual costs. | Provides visibility of costs to aid project learning | Removes the incentive to be cost efficient, and often results in gold plating.<br>Time consuming |
| Bilateral negotiations with each participant to agree the fee | - | NG want to move away from bilateral contracts as they prevent cost transparency<br>Resource intensive |
| Annual availability payment | Potential to secure a lower £/hr availability payment because of the security given from firm agreement | Exposes project to high utilisation bids and increases the complexity of the assessment as decision will be taken without all inputs needed to do so |

The Panel were also asked, "what would appropriate length and proportion of the budget for each wave would be, to achieve our objectives?". Several options were debated and table 18 summarises the views put forward by the panel members.

Table 18: Regional market Advisory Panel discussion on payment options

| Option | Pros | Cons |
|---|---|---|
| Equal proportions to wave 1, 2 and 3 | Simple, easy to understand | Not all waves provide equal value in learning to the project e.g. waves 1 and 2 most valuable |
| Treat wave 3 as a decision point and allocate zero budget | Broad support for this amongst panel, saw waves 1 and 2 as priority and if they failed wave 3 would be redundant anyway | How to prepare DERs for 'soft landing' to business as usual without a wave 3? |

| Option | Pros | Cons |
|---|---|---|
| Equal proportions to waves 1 and 2 | Ensures demonstration of technical solution whilst informing price discovery (both to project and to future market participants) | How to manage the risk that there won't be enough budget for all interested participants |
| Majority of budget on wave 2 | Some panel members felt this was the most valuable part of the project – informs longer term view | How to ensure we get to wave 2 If we do not sufficiently fund wave 1? One panel member stated that "if wave 2 has a scarcity problem, it is because wave 1 has failed to attract participants" |
| If a cap is applied in wave 3, also apply a floor | Prevents 'race to the bottom' | Risk of artificially high prices to SO and therefore the end consumer |

Because of this feedback from the Regional Market Advisory Panel, the broad principles applied to the service payment budget used for the design of the trials are:

- Wave 1 is intended to cover most upfront costs for most participants (i.e. partially de-risk through offering some certainty of revenue).
- The budget aims to be split equally between wave 1 and wave 2.
- There will be no budget for wave 3 payments to participants from the project budget; instead payments would be made from a business as usual approach though National Grid's balancing services budget.

#### 7.4.5 Finalising the trials through consultation with interested DERs and the Regional Market Advisory Panel

In May we shared the updated trial design via a webinar and published a draft framework agreement and market procedure for the Power Potential trial. An overview of the key features of each reactive power trial wave is presented in Table 19.

Table 19: Reactive power trial structure

| Wave | Funding from | Participation fees | Availability payment policy | Utilisation payment policy |
|---|---|---|---|---|
| 1 | Power Potential budget | Up to £18,000-£20,000 per site, linked to performance | No payments | No payments |
| 2 | Power Potential budget | N/A | Driven by market bids | Driven by market bids |
| 3 | BAU budget | N/A | Assessed in line with transmission alternative actions | |

Bilateral discussions were then held with all DER who wished to discuss the details of the revised commercial proposition with the project team and a third Regional Market Advisory Panel meeting took place. These activities and the formal consultation explained in chapter 5 informed the project team as to what final adjustments needed to be made in order to maximise participation during Power Potential's 2019 trial.

A summary of this feedback and how we incorporated it is presented in Table 20:

**Table 20: Regional Market Advisory Panel and DER feedback on the commercial proposition and the project team's approach**

| RMAP & DERs said… | We did… |
| --- | --- |
| **Participation payments**<br><br>Having done more detailed scoping of investment requirements our anticipated costs are higher than previously anticipated; the project must guarantee these can be recovered to enable us to participate. | Asked DERs to share as much information as possible with us on anticipated costs, giving us a revised average CAPEX cost of ~£41,000. |
| **24/7 availability requirement for wave 1 not achievable for all providers**<br><br>Several DERs interested in participating in the trial are solar providers who can only offer reactive power services at night; meaning they will not be able to recover most of their costs from the participation payment based on current availability thresholds. | Availability thresholds relaxed slightly with wave 1 period extended to allow greater opportunity for DERs to hit the thresholds. |
| **Utilisation payment for wave 1**<br><br>Lack of utilisation payment for wave 1 makes it less attractive to make entire MVAR range available in this part of the trial. | An increased availability payment is in place to help overcome this hurdle. As effectiveness of service delivery will be deduced during wave 1 no utilisation fee will be paid, though utilisation is anticipated to be low during these hours. |
| **Firm go-ahead on trial**<br><br>Risk to participants if the trial doesn't proceed, only get wave 1 participation, nothing for loss of opportunity in wave 2/3 but initial wave 1 participation payment doesn't cover costs for some DERs. | Decision to pay up to the maximum value of participation payment available, but on an 'open book' basis (i.e. pay at cost if DER costs < participation payment value) to aid project learning. |

## 7.5 Detailed description of waves

### 7.5.1 Introduction and overview

Payments to DERs will differ depending on the wave, given their different functions. These payments will include:

- Participation payments (linked to overall performance in wave 1 of the trials).
- Market revenues (from payments for availability and utilisation during wave 2 and wave 3).

An overview of the key features of each reactive power trial wave is presented in table 21:

**Table 21: Reactive power trial structure**

| Wave | Funding from | Participation fees | Availability payment policy | Utilisation payment policy |
|---|---|---|---|---|
| **1** | Power Potential budget | Up to £45,000 per site, linked to performance | No payments | No payments |
| **2** | Power Potential budget | N/A | Driven by market bids | Driven by market bids |
| **3** | NG BAU budget | N/A | Assessed in line with transmission alternative actions | |

### 7.5.2 Wave One Participation – final design: Eligibility and timings

All participants who sign up to the Framework Agreement will be eligible to participate in wave 1 subject to passing the commissioning phase. Wave 1 is planned to commence early in 2019 – the date will be confirmed towards the end of 2018. The wave will be split into a winter phase and a summer phase to allow technical trials to cover both seasons. Precise dates for the transition between waves will be confirmed closer to the time.

Before a DER unit can participate in the optional technical trial (which participation payments are linked to) it must complete a period of mandatory technical trials. Mandatory technical trials will be carried out during the first two weeks of the wave 1 trials, with trial windows two hours in length across two days; the timing of which will be agreed with DER[15]. A document containing further details of these trials will be produced in due course.

### 7.5.3 Wave One Participation – final design: Participation process

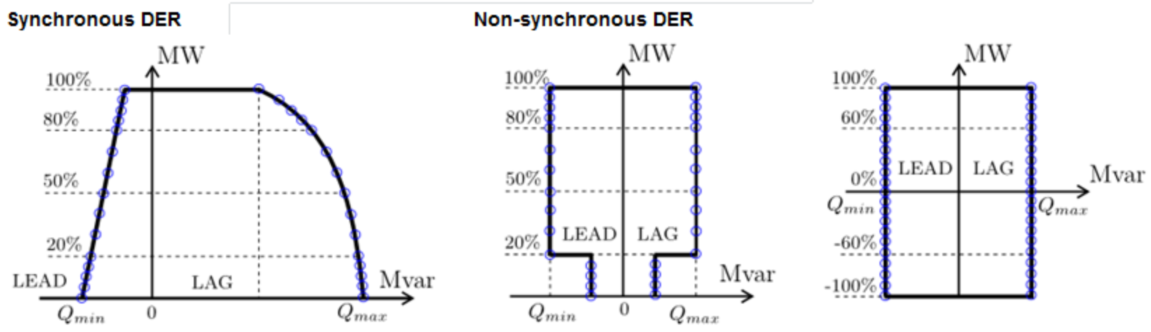
For the reactive power service, wave 1 optional technical trials will take place after the mandatory technical trials and they will cover two periods in winter and summer. Winter trials and summer trials are expected to run continuously for a fixed number of weeks, with DER's availability being required 24 hours a day for the full winter trials and summer trial periods. There are several steps to participate in the operational technical trials:

- As part of prequalification, DERs will have submitted their PQ capability chart (see Figure 18), which will have been verified through commissioning testing.
- Before the beginning of the winter trial and before the beginning of the summer trial period, DERs will be required to submit their availability for reactive power for the whole winter trial or summer trial period. These availabilities could be amended[16], if the DER expectations change during this time.

[15] DERs that cannot carry out mandatory technical trials in the first two weeks of the trial will not be able to offer availability for optional technical trials until they have completed their mandatory technical trials. We will work with DERs to schedule these as soon as possible to maximise a DER's chances of maximising their participation payments for the optional technical trial.

[16] Meaning that the DER could opt out/in of the Reactive Power service. Availability definition is covered in the next Settlement and Payment section of this document and refers to the DER capability to provide the service not to the reactive range available.

Figure 18: Illustration of reactive and active service availability via PQ capability chart




Submission of availability for the reactive power operational technical trials will be done through the web interface.

In addition, DERs will have the possibility to provide additional information associated to its availability windows:

- For each trial day, by 2pm the day before DERs could have the option to provide a half-hourly forecast of their active power expected operating levels, which in conjunction with the PQ capability chart (see Figure 17) and the UK Power Networks connection agreement limits, the forecast reactive availability. This will be used as a learning, both for the DERs and the Power Potential project to prepare for wave 2.

#### 7.5.4 Wave One Participation – final design: Settlement and Payment

Once the mandatory technical trials have been completed, and subject to the number of hours DERs are available for in wave 1, each DER can earn up to £45,000 in participation payments for participation in the wave 1 optional technical trials.
Participation payments will be made on a per DER connection basis, split across the two wave 1 trial periods (the winter trial and the summer trial) and linked to reactive power availability during these periods.

Of the maximum available participation payment:

- 50% will be payable for the optional technical trial in the wave 1 winter trial period
- 50% will be payable for the optional technical trial in the wave 1 summer trial period.

The total amount that each DER will receive for each of the trial periods will be linked to performance, determined by reference to availability thresholds (table 22). Performance against availability thresholds will be determined by a DER's declared day-ahead availability, de-rated downwards proportionate to the number of hours that it fails to deliver reactive power when requested.

A DER will be deemed to be have delivered when available:

- If non-synchronous when it is online generating active or reactive power and operating, for a given active power output, in voltage droop control mode within its declared reactive capability range and within UK Power Networks' network connection agreement limits.

- If synchronous when it is online generating active or reactive power and operating, for a given active power output, in voltage control mode within its declared reactive capability range and within UK Power Networks' network connection agreement limits

Availability will be measured at the end of each of the Wave 1 Optional Trial Periods. If a site was available for over 1850 hours, it will receive the maximum £45,000 participation payment.

**Table 22: Wave 1 participation payment values recoverable per DERs availability**

| Amount recoverable | Availability hours |
|---|---|
| £36,000 | <=700 |
| £38,000 | <=1000 |
| £41,000 | <=1300 |
| £43,000 | <=1500 |
| £45,000 | <=1850 |

Payments will be made following the end of each of the wave 1 trial periods, not later than 30 days after the end of trial period.

| | | | | | | |
|---|---|---|---|---|---|---|
| A summary of the **Participation Payments** calculation is as follows: **Participation Payments Winter Trial (£)** | = | Total Participation Fee Payable (£) | x | 50% | x | % recoverable in relation to Availability Thresholds |
| **Participation Payments Summer Trial (£)** | = | Total Participation Payable (£) | x | 50% | x | % recoverable in relation to Availability Thresholds |

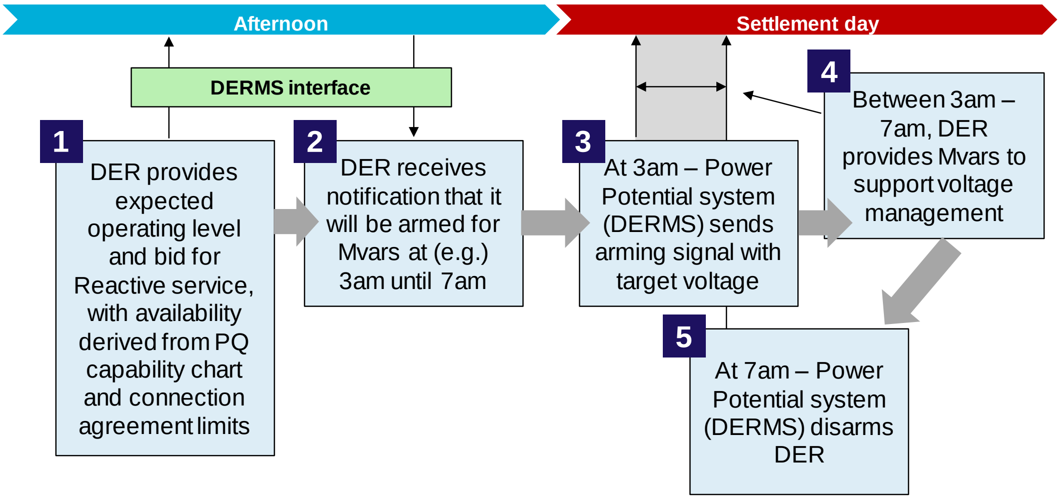
If the Power Potential trial does not go ahead, providers will receive up to the maximum value of participation payment available, but on an 'open book' basis (i.e. pay at cost if DER costs < Participation Payment value).

## 7.6 Wave 2 – updated design

### 7.6.1 Wave 2 - Participation process

DERs must have completed the mandatory technical trials to participate in wave 2. The process for participation in wave 2 is like that for wave 1, with the key difference being that this wave introduces competition between participants, with each specifying both an availability price and a utilisation price. In some periods, DERs may have made themselves available but will not be accepted by the DERMS. The process for tendering is summarised in Figure 19.

Figure 19: Tendering process




As with wave 1, DERs will indicate their availability for the active and reactive service in three steps:

1. By submitting a forecast of the MW operating level for each half-hour period over the following day.
2. Using the DER's PQ capability chart and connection agreement limits.
3. By indicating their willingness to offer one or both active and reactive power services to the DERMS.

In wave 2 there is an additional step, which is that for each service window DERs need to indicate an availability price (£/Mvar/hr) and a utilisation price (£/Mvarh) for reactive power. If successful, DERs will receive payment on a pay-as-bid basis.

The market will be run for a minimum of 1,800 hours, with the intention of running more if the trial budget allows. This will typically be achieved by running Power Potential auctions every other week (on weeks with even numbers) during wave 2 for all weekdays, and alternating between Saturday and Sunday for each market week, as illustrated in table 23.

Table 23 - Illustrative market windows for wave 2

| Week number | Auction run (Monday – Friday ) | Saturday or Sunday |
|---|---|---|
| 8 | Y | Saturday |
| 9 | N | |
| 10 | Y | Sunday |
| 11 | N | |
| 12 | Y | Saturday |

#### 7.6.2 Wave 2 -Acceptance criteria[17]

At a high level, Power Potential is designed to mimic the situation in which National Grid procures the Power Potential services directly from providers, but does so via the DERMS. The DERMS collects availability and utilisation bids by each provider, carries out network analysis and presents an adjusted stack to National Grid (where the adjustment is described in more detail below). National Grid then determines what proportion of that stack to accept, with the DERMS then indicating to the corresponding providers that they have been successful at their tendered price.

From a provider's perspective, assuming they can deliver what they commit to, they will receive payment in line with their bids. For example, if a provider offers 1 Mvar of response for 1 hour at a price of £5/Mvar/h with a utilisation bid of £10/Mvarh, and is accepted on that basis they will receive £5 for that hour plus any utilisation paid at the bid price. However, providers should be aware that the acceptance of a provider's bid will depend on other factors. The primary factor that will be considered is the 'sensitivity' of a provider to a GSP.

The sensitivity value is defined as follows:

> *Sensitivity value is an indicator of the effectiveness of a DER reactive power injection in a particular GSP. Allocation of a DER to a particular GSP is done according to where this value is shown to be maximum (GSP reactive power variation $Q_{GSP}$ divided by DER reactive power variation of $Q_{DER}$).*

This is the key adjustment made by the DERMS. A GSP (or any point on the network) will be more sensitive to the injection or absorption of reactive power at some network locations than others. Some DER sites can resolve network issues more effectively than others. Therefore, two providers with identical bids could be seen differently by the DERMS, and hence by UK Power Networks. It may be that a provider with a low bid but low sensitivity value is rejected in favour of a provider with a higher bid but high sensitivity value.

Providers should therefore be aware that their sensitivity relative to other providers could be a key determinant of the frequency with which their bids are accepted. A provider with low sensitivity might need to lower their bid to increase the frequency with which their bids are accepted.

Both the availability and utilisation price will be factored into the adjusted stack presented to National Grid, considering a forecasted utilisation of each DER calculated by the DERMS.

#### 7.6.3 Wave 2 - Measuring, settlement and payment

Response will be measured at the point of connection of the provider's site. The Power Potential project may make separate measurement of the service at different points on the network (e.g. Grid Supply Point) but this will not be used for settlement purposes. This is a key learning outcome for the project and as such the project will bear this risk. Providers should be aware that this would be reviewed should a Power Potential service be rolled out as business as usual.

[17] Note that whilst the Power Potential team wishes to be fair and transparent about the acceptance criteria, it should be recognised that this is a trial and, as such, any of the decision-making criteria are subject to change. Any such changes will be communicated clearly to all impacted parties, before changes take place.

DER reactive service providers will receive:

- Availability payments for reactive power availability accepted in the Power Potential auction
- Utilisation payments for reactive power response.

Availability prices (£/Mvar/hr) and utilisation prices (£/Mvarh) will be the prices submitted by DER providers as bids for service windows at the day-ahead stage, and will be paid on a pay-as-bid basis.

The total availability payments received will be adjusted for a DER performance. This means that at the end of each month, the aggregate number of settlements periods in which the DER was accepted and deemed to have been available (as measured under the logic specified for wave 1) is compared to the total number of settlement periods that the DER service was accepted for, to calculate a relevant proportion of availability achieved.

If a DER provider's relevant proportion is less than 80% in a month, then it will be assigned a performance factor equal to the relevant proportion and total availability payments for the month will be scaled down by this ratio.
A summary of the relevant proportion calculation is as follows:

$$\text{Relevant Proportion (\%)} = \frac{\text{Total Settlement Periods accepted and available}}{\text{Total Settlement Periods accepted}}$$

The logic for the Performance factor is as follows:

***If Relevant Proportion < 80%, Relevant Proportion = Performance Factor***

A summary of the calculations for Utilisation and Availability Payments are as follows:

$$\textbf{Total Availability Payments each month (£)} = \text{Sum for each Settlement Period} \left\{ \text{Reactive Power Availability Volumes (Mvar)} \times \text{Reactive Power Availability Prices (£/Mvar/hr)} \right\} \times \text{Performance Factor (\%)}$$

$$\textbf{Total Reactive Utilisation Payments (£)} = \text{Sum for each Settlement Period} \left\{ \text{Utilisation Volumes (Mvarh)} \times \text{Utilisation Fee (£/Mvarh)} \right\}$$

At the start of the service window, the DERMS will arm DERs in voltage control/voltage droop control mode and adjust their voltage set point to achieve a Mvar output equal to zero. Initially, the voltage set-point will match the local DERs measure voltage of the distribution network. This has the effect of initially maintaining the Mvar produced by the DER. Subsequent iterations on the voltage set point will bring the DER's Mvar output to zero.

The baseline output level will be set against the Mvar output prior to the start of the service window. Reactive power utilisation over a service window is therefore the change in the Mvar output of active power injection/absorption for each [half hour] summed over the [x] half hours of the service window.

Reactive power utilisation over a service window is the absolute difference between baseline and the actual reactive power injection/absorption for each [half hour] summed over the [x] half hours of the service window.

### 7.7 Wave 3 – updated design

From the DER's perspective, wave 3 will operate in a similar manner to wave 2. There are key features that should be noted:

- Wave 3 will only commence if National Grid determines that the service is competitive with options already available to it on the transmission system.
- Power Potential services, if accepted, will be used to secure the system.
- Wave 3 bids will be met from National Grid's business as usual budget rather than the Power Potential trial budget.
- Bids will be assessed in line with the cost of alternative actions.
- National Grid will only accept the DERMS volumes where the price is lower than the alternatives available to it, after consideration of effectiveness, meaning that some (or all) DERs may not be accepted if they cannot reduce their bids to a competitive level.

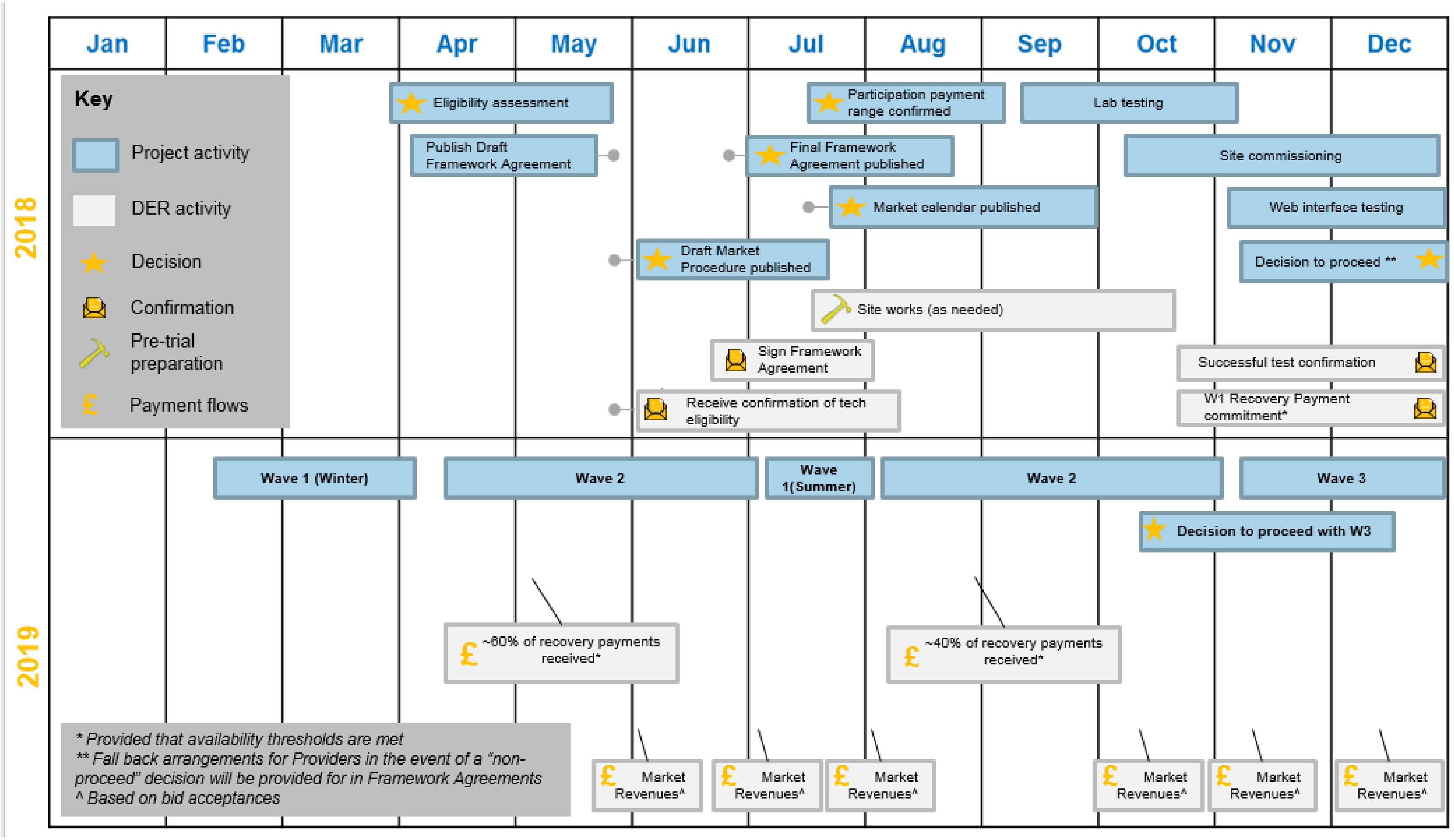
### 7.8 Commercial data and financial flows

The trials will commence in 2019 in line with the market calendar. Our intent is for the first trial to commence mid-February 2019, and this will be wave 1 winter, as illustrated in Figure 20. All settlements will be made 30 days after delivery. Payment for wave 1 will take place early May 2019, following an assessment of wave 1 availability with up to ~50% of the recovery payment available here.

Wave 2 will then commence and will likely consist of a week of competitive auctions, a week off, a week on, a week off. DERs whose bids are successful will receive market revenues in line with their bid prices. Wave 1 optional technical trials will then take place during the summer and following an assessment of availability, up to ~50% of the recovery payment available here. Wave 2 competitive auctions will recommence and then a decision to proceed with wave 3 trials will be made and communicated to DERs and commence at the agreed date.

In line with the contractual arrangements, all payments are back to back. National Grid will make payment to UK Power Networks a few days before payment is due to DERs and payment will be made based on what is metered at the DER point of connection for utilisation and what is bid for availability (in line with performance factors).

Figure 20: DER Pathway to participation and payment schedule



# 8. Forecast availability and utilisation

## 8.1 Introduction

This chapter presents and analyses the technical data submitted by potential DER participants to determine forecasted volumes for the Power Potential project trials. As mentioned in chapter 4, in February 2018, DERs in the trial region were asked to complete a *Technical Characteristic Submission Spreadsheet* (TCSS) to formally express their interest to participate in the Power Potential project. The spreadsheet was produced by the project team and was accompanied by a guidance document to help its completion.

The information submitted by DERs in their TCSSs has been processed to determine the capabilities declared by the DERs (without taking into consideration distribution network limits such as thermal and/or voltage limits but including DER's connection agreement restrictions) to provide services under Power Potential and to identify any possible technical limitations. With this information, an estimation of the volumes expected for the trial, subject to DERs signing their framework agreements, has been produced.

## 8.2 Power Potential services and TCSS requirements

To better understand how forecasted volumes for the project trials have been calculated, the technical specifications of the two services that can be provided by DERs through Power Potential are summarised in this section

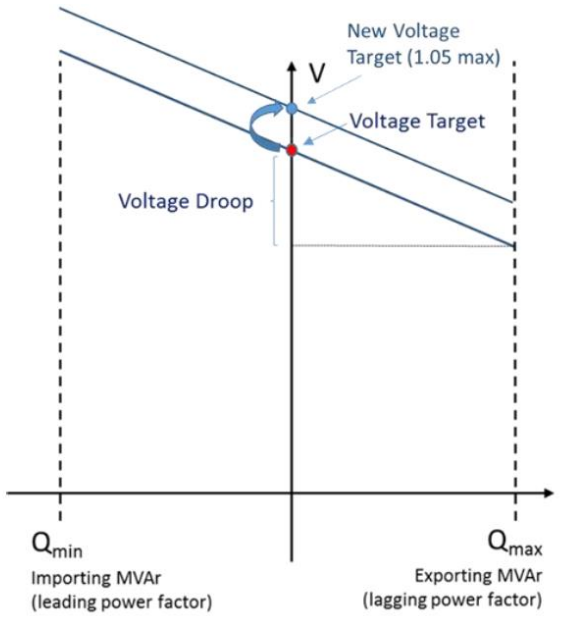
Under the Power Potential innovation project, DERs will be able to provide reactive power services and/or active power services to the GB System Operator providing a new option to manage transmission constraints.

### 8.2.1 Reactive Power service

The reactive power service is aimed to provide dynamic voltage support, like an SVC/STATCOM reactive compensation device or transmission connected generators. In the reactive power service, non-synchronous DERs would be instructed at their point of connection using voltage droop control to produce/absorb reactive power. Synchronous DERs would be instructed using a voltage target set-point to adjust the generator terminal voltage to produce/absorb reactive power. This production/absorption of reactive power would allow more effective control of the voltage in the transmission system.

The principles behind voltage droop control are presented in Figure 21. The reactive power exported by the DERs is controlled based on a voltage target and a reactive power slope, also known as voltage droop control. Therefore, a change between the measured voltage and the desired voltage target at the DER point of connection will translate in a reactive power injection from the DER proportional to this voltage difference.

Figure 21: Voltage droop control principles




Specific conditions for the participation of DERs in the reactive power service are set as follows:

- The non-synchronous DERs should be capable of operating in voltage droop control to automatically deliver changes in reactive power in response to system voltage changes. The synchronous DERs should be capable of operating to a target voltage set-point to automatically deliver changes in reactive power in response to system voltage changes. Reactive power service participants are expected to be online (armed) in the operating status indicated above when participating in the reactive power service. This will allow DERs to automatically deliver changes in reactive power in response to system voltage changes.
- The non-synchronous DERs should be able to automatically, on instruction from the DERMS, sweep between voltage droop control and power factor control in an expected time of 10 seconds. The synchronous DERs should be able to automatically, on instruction from the DERMS, sweep between target voltage control and power factor control in an expected time of 10s. In addition, it is expected that any change in voltage target set-point received electronically should be 90% achieved within 2 seconds and 100% achieved in 5 seconds.
- The non-synchronous DERs should be able to change the voltage set-point of its voltage droop control upon UK Power Networks' request. The synchronous DERs should be able to change the voltage set-point of its target voltage control, upon UK Power Networks' request.
- DERs should be capable of moving their operating point and change reactive power output from 0 to 90% of its maximum export capability (full lag) within 2 seconds and from 0 to 90% of its maximum import capability (full lead) within 2 seconds. This condition could be relaxed after evaluating DER's submitted values.

### 8.2.2 Active power service

The active power service is a real-time service[18] expected to improve the management of thermal constraints at the transmission level. In the active power service, both synchronous and non-synchronous DERs would be instructed to an active power set-point. Specific conditions for the participation of DERs in the active power service are set as follows:

- The DERs should be able to deliver and manage, upon UK Power Networks' request, a net change in the import or a change in the export as seen by the distribution network.
- The DERs should be able to declare a minimum running time of half an hour i.e. to declare a capability that can be maintained for half an hour.

Together with the verification and acknowledgment of these points, DERs were asked to submit different technical parameters to confirm the capabilities in the plant operating range, identify potential needs for upgrade and determine latencies in the communication and control systems.

## 8.3 Summary of (unfiltered) DER's TCSS submissions

As of 15 June 2018, a total of **13 companies** have submitted the requested DER *technical characteristics submission spreadsheet* (TCSS) for a total of **19 sites**. These DER sites correspond to a range of different technology types: PV solar, wind farms, battery storage and synchronous generators. A summary of the total unfiltered submissions with some relevant parameters is presented in table 24. Out of these submissions, one company did not identify any potential site and one submission was for a site that is connected outside of the project area. This means 17 sites submitted valid TCSS submissions.

It is important to reiterate that all the numbers reported below are based purely on the DER's submissions and can change depending on how many of these DER proceed to trials.

Table 24 - Unfiltered total DER submissions

| DER participant | GSP | kV | Type | P declared* (MW) | Q LAG declared* (Mvar) | Q LEAD declared* (Mvar) |
|---|---|---|---|---|---|---|
| 1 | Ninfield | 132 | Wind Farm | 59.80 | 19.80 | 19.80 |
| 2 | Ninfield | 132 | Battery Storage | 40.00 | 20.00 | 30.00 |
| 3 | Ninfield | 33 | Battery Storage | 32.40 | 30.00 | 30.00 |
| 4 | Ninfield | 33 | PV Solar | 19.00 | 20.90 | 19.00 |
| 5 | Bolney | 33 | Synchronous | 19.10 | 2.00 | 0.50 |
| 6 | Ninfield | 11 | PV Solar | 8.90 | - | - |
| 7 | Bolney | 132 | Battery Storage | 35.00 | 32.40 | 32.40 |

[18] DER will not be instructed/contracted ahead of real time.

| DER participant | GSP | kV | Type | P declared* (MW) | Q LAG declared* (Mvar) | Q LEAD declared* (Mvar) |
|---|---|---|---|---|---|---|
| 8 | Ninfield | 33 | PV Solar | 4.50 | 1.50 | 1.50 |
| 9 | Ninfield | 33 | PV Solar | 6.00 | 6.60 | 6.00 |
| 10 | Ninfield | 33 | PV Solar | 5.34 | - | - |
| 11 | Bolney | 33 | PV Solar | 6.80 | 2.38 | 2.38 |
| 12 | Canterbury North | 33 | Wind Farm | 49.90 | 16.00 | 16.00 |
| 13 | Canterbury North | 132 | PV Solar | 38.7 | 16.70 | 16.70 |
| 14 | Bolney | 33 | Battery Storage | 9.60 | 9.60 | 9.60 |
| 15 | Bolney | 33 | Battery Storage | 5.50 | 5.50 | 5.50 |
| 16 | Canterbury North | 11 | Synchronous | 3.00 | 2.4 | 2.0 |
| 17 | Bolney | 33 | PV Solar | 8.18 | - | - |

*Quoted values do not take into consideration distribution network limits such as thermal and/or voltage limits.

The 17 valid expressions of interest in table 24 correspond to a total volume of approximately 353 MW with an associated 186 Mvar (lag) and 192 Mvar (lead) capability[19]. However, three of the sites correspond to battery storage projects that are not yet connected (DER 3, DER 7 and DER 15), and two other sites were removed after discussion with the interested company (DER 6 and 10), which decided to concentrate their efforts in two other locations. Finally, DER 16, after several technical discussions and evaluation of upgrades needed for a synchronous plant, also decided to withdraw from the project and leave the generator to pursue its primary agricultural function. All these submissions are marked in orange / red in the table and are not considered in the subsequent calculations. This leaves us with **11 potential sites** under technical evaluation to participate in Power Potential to provide active and reactive power services.

Note that the sites marked in orange have been excluded from the analysis of forecast volumes in the trials in sections 8.4 and 8.5 as these sites are not yet connected. These sites could be considered as feasible participants later in the project if they finalise their energisation process in time for the Power Potential trials. At the time of writing, in this category, only DER 7 is progressing with its connection application.

[19] Reactive capability only counted when data was completed in the TCSS.

## 8.4 Reactive power forecasted maximum DER volumes

### 8.4.1 Reactive volume calculations at the DER Point of Connection (POC)

Table 25 presents relevant data for the reactive power service from the 11 sites mentioned before. To calculate the potential DER reactive power volumes available for the trials (initially without taking into consideration distribution network constraints), the plant P-Q capability charts submitted by DERs have been used. Declared lead and lag maximum reactive power values are summarised in table 25 for each DER together with declared associated response times ($t_{exp}$: time from 0 to 90% of the maximum reactive export, $t_{imp}$: time from 0 to 90% of the maximum reactive import and capability to react to a voltage set-point instruction within 2 seconds). It is to be noted that, in some cases, reactive power capability depends on the DER active power output and that table 25 presents maximum values.

The last column in the table corresponds to the estimated effectiveness of DER's injections at their POC in the transmission level Grid Supply Points (GSP). This effectiveness is only listed for the GSP in which this value is maximum (some DERs are effective at more than one GSP due to the configuration of the distribution network) and where the DER is initially allocated to. This data was calculated by UK Power Networks following several distribution network studies and was not submitted by the DERs in their TCSSs. When the project goes live, these values, which depend on the distribution network configuration and might change under various operational conditions (known as running arrangements), will be continuously calculated by the DERMS and provided to the customer via the DERMS-DER web-interface.

Table 25: Filtered DER submissions for the reactive power service

| DER | GSP | Any issues? | Q LAG declared (Mvar) | Q LEAD declared (Mvar) | $t_{exp}$ declared (s) | $t_{imp}$ declared (s) | $t_{vset}$ (s) < 2s? | Estimated Effect |
|---|---|---|---|---|---|---|---|---|
| 1 | Ninfield | NO | 19.80 | 19.8 | < 1 s | < 1 s | YES | 87% |
| 2 | Ninfield | NO | 20.00 | 30.00 | < 1 s | < 1 s | YES | 86% |
| 4 | Ninfield | NO | 20.90 | 19.00 | TBC | TBC | YES | 45% |
| 5 | Bolney | YES | | | < 5 min | < 5 min | NO | 36% |
| 8 | Ninfield | NO | 1.50 | 1.5 | 1-2 s | 1-2 s | YES | 89% |
| 9 | Ninfield | NO | 6.60 | 6.00 | TBC | TBC | YES | 52% |
| 11 | Bolney | NO | 2.38 | 2.38 | 5 s | 5 s | YES | 37% |
| 12 | Canterbury North | NO* | 16.00 | 16.00 | <5s | <5s | YES | 72% |
| 13 | Canterbury North | NO | 16.9 | 16.9 | < 2s | < 2s | YES | 72% |
| 14 | Bolney | NO | 9.60 | 9.60 | < 1s | < 1s | YES | 67% |
| 17 | Bolney | NO | TBC | TBC | TBC | TBC | TBC | 37% |

In table 25, following their initial TCSS submission, several sites were identified to have potential issues (technical or commercial) to participate in the trials. DER 5 submitted high response times (in the order of minutes) that limit its participation in the reactive power service to provide dynamic voltage control. DER 12 also reported high response times on its TCSS (60 seconds) but after discussions and clarification, it was confirmed that these response values are expected to be below 5s. DER 13, although having good response times initially communicated that it will need to carry out significant investment (in the order of £500k) to participate in the project to extend the plant capabilities. However, they will no longer pursue this upgrading option and use the existing plant capability range which significantly reduces this figure. Finally, DER 17 did not submit any technical reactive information but there is no concern that the plant will not meet the technical criteria and its information will be updated in due course. Therefore, only DER 5 and DER 17 (due to lack of information) are provisionally excluded from the expected reactive volume calculations presented next.

The information in table 25 is summarised in DER volumes per GSP in table 26. Note that these calculations reflect only the 9 DER sites which are currently considered by the project team as having potential to participate in the Power Potential trials (marked as green in table 22 based on the declared values, and where no major commercial/technical issues have been identified. It should be noted that none of these DERs are certain to proceed, and engagement continues with other DERs that still could progress to trial. These results are the project team's expectations on 15 June 2018.

Table 26: Expected reactive power volumes per GSP at the DER POC level, according to DER TCSS

| GSP | Number of DER | DER POC Q LAG declared (Mvar) | DER POC Q LEAD declared (Mvar) |
|---|---|---|---|
| Bolney | 2 | 11.98 | 11.98 |
| Ninfield | 5 | 68.8 | 76.3 |
| Sellindge | 0 | 0 | 0 |
| Canterbury North | 2 | 32.87 | 32.87 |
| **TOTAL** | **9** | **113.65** | **121.15** |

As demonstrated in table 26 (and applying the filtering process described before), at the DER level, there is an expected total volume of approximately 113 Mvar of lag capability and 121 Mvar of lead capability available for the reactive power service without taking into consideration any thermal or voltage restrictions on the distribution network.

### 8.4.2 Reactive volume calculations at the Grid Supply Points (GSP)

The DER's reactive power injections at their point of connection (POC) calculated before will not fully be reflected at the transmission level Grid Supply Points (GSP) because of both reactive losses between the DER's POC and the GSP, and distribution network operational limits (thermal and voltage) that need to be respected. This section focuses on the former. The following section then considers the latter. It is important to calculate the volumes that will be delivered at the GSP given that Power Potential is offering the service at the transmission level. Using the maximum effectiveness values[20] from table 24 provided by UK Power Networks, an estimation of the expected reactive volumes at the GSP transmission level is presented in table 27.

It shows the expected volumes at the GSP level without considering any coupling effect in the calculations. This means that the effect of the DER local injection is only accounted for the GSP at which it is most effective (and where it has been allocated to). This is a conservative

[20] Effectiveness or sensitivity value is an indicator of the effectiveness of a DER reactive power injection in a particular GSP. Allocation of a DER to a particular GSP is done according to where this value is shown to be maximum (GSP reactive power variation $Q_{GSP}$ divided by DER reactive power variation $Q_{DER}$).

approach but applies one of the project commercial principles in which each DER's effect is allocated to a single GSP. In this way, we can identify four virtual power plants in table 27 over which the TSO will have control (i.e. these are the volumes that will be presented to the control engineer, excluding any coupling effect).

Table 27 - Expected reactive power volumes at the GSP 400kV level according to DER TCSS – no coupling considered

| GSP | Number of DER | GSP Q LAG (Mvar) | GSP Q LEAD (Mvar) |
|---|---|---|---|
| Bolney | 2 | 7.34 | 7.34 |
| Ninfield | 5 | 48.63 | 56.08 |
| Sellindge | 0 | 0 | 0 |
| Canterbury North | 2 | 23.65 | 23.65 |
| **TOTAL** | **9** | **79.62** | **87.07** |

However, in reality, DER injections will affect neighbouring GSPs and not only the one which it is allocated to. In this sense, table 28 shows the effect of DER at other GSP as well, including coupling effects caused by the network configuration.

Table 28: Expected reactive power volumes at the GSP 400kV level – coupling considered

| GSP | Number of DER | GSP Q LAG (Mvar) | GSP Q LEAD (Mvar) |
|---|---|---|---|
| Bolney | 2 | 7.34 | 7.34 |
| Ninfield | 5 | 50.89 | 58.34 |
| Sellindge | 0 | 25.90 | 25.81 |
| Canterbury North | 2 | 28.54 | 28.51 |
| **TOTAL** | **9** | **112.67** | **120.00** |

### 8.4.3 Reactive power service: DER's connection agreement distribution network power factor restrictions to volume calculations

The GSP volumes presented before do not consider any distribution network restriction in the total calculations. DERs will need to operate without violating any distribution network constraints and the DERMS will enforce this. In addition, DERs will need to operate within the limits of their existing connection agreements with UK Power Networks. This agreement usually imposes a power factor restriction of the plant output to operate within the network security limits. The power factor limit is commonly set to 0.95, lead and lag. As described in section 5.4, UK Power Networks has completed power factor studies for each DER that has submitted a TCSS to investigate if they can dispatch larger volumes of reactive power whilst not violating local distribution network operational voltage limits. Table 29 shows how the GSP volumes in table 27 are affected by the existing connection agreement limits for the nine DER under evaluation. In the case in which the connection agreement is less restrictive than the reactive capability declared by a DER in its TCSS, the former value (minimum of the two) was used.

Table 29: Expected reactive power volumes at the GSP 400 kV level according to DER TCSS and existing DER connection agreement – no coupling considered

| GSP | Number of DER | GSP Q LAG (Mvar) | GSP Q LEAD (Mvar) |
|---|---|---|---|
| Bolney | 2 | 2.80 | 2.80 |
| Ninfield | 5 | 32.86 | 32.86 |
| Sellindge | 0 | 0 | 0 |
| Canterbury North | 2 | 19.91 | 20.21 |
| **TOTAL** | **9** | **55.57** | **55.87** |

By comparing the GSP volumes in table 28 and table 29, available reactive volumes are reduced by half. Therefore, investigating if it is possible to relax the existing DER connection agreement power factor limits might lead to achieving larger volumes of reactive power available at the GSP level. UK Power Networks has carried out detailed power system studies to evaluate the extension of the power factor operating range for each DER. These details will be shared which each individual participant which could decide to amend their existing connection agreement to apply this new range, or not. Table 30 shows how a new power factor operational range for the considered DERs could increase the total reactive volume, at the GSP level if all nine DERs accept a new power factor range.

Table 30: Expected reactive power volumes at the GSP 400kV level according to DER TCSS and new power factor range in DER connection agreement – no coupling considered

| GSP | Number of DER | GSP Q LAG (Mvar) | GSP Q LEAD (Mvar) |
|---|---|---|---|
| Bolney | 2 | 7.34 | 7.34 |
| Ninfield | 5 | 34.72 | 35.99 |
| Sellindge | 0 | 0 | 0 |
| Canterbury North | 2 | 23.35 | 23.35 |
| **TOTAL** | **9** | **65.41** | **66.68** |

Within the existing distribution network operational limits, the improvement shown in table 29 by extending power factor range is in the order of 15-17%.

### 8.5 Active Power forecasted maximum DER's volumes

In this section the volumes expected for the active power service are presented, aligned to the DER's submissions. From the 11 sites mentioned at the beginning of this chapter filtered from the total 19 submissions, table 31 evaluates their submitted information to participate in the active power service. Several sites expressed explicitly that they were not interested in this service and are marked in orange. The rest of sites completed the active power information data and so are considered in the expected active power volumes. Note that solar providers will be only interested in the service if the price is right (better than ROC tariffs).

To the maximum volumes identified for reactive power, no additional filtering has been applied here based on DER's expectation of revenue they would need to receive from the active power service to offer the volume – this is purely indicative of technical capability.

Table 31: Filtered DER submissions for the active power service

| DER participant | GSP | Interested in P service? | P (MW) |
|---|---|---|---|
| 1 | Ninfield | YES | 59.80 |
| 2 | Ninfield | NO | |
| 4 | Ninfield | NO (PV) | |
| 5 | Bolney | YES | 19.10 |
| 8 | Ninfield | NO | |
| 9 | Ninfield | NO (PV) | |
| 11 | Bolney | YES* (PV) | 6.80 |
| 12 | Canterbury North | NO | |
| 13 | Canterbury North | NO (PV) | |
| 14 | Bolney | YES | 9.60 |
| 18 | Canterbury North | NO | |
| 19 | Bolney | NO | |
| | | **TOTAL (MW)** | **95.3** |

A total volume of 95.3 MW for the trial period results from these participants. However, these numbers are provisional and could change since some of the DERs may not be able to accommodate the active power service with their existing operation and provision of other balancing/frequency services. Table 32 summarises the total active power volumes per GSP.

Table 32: Expected active power volumes per GSP at the DER's POC level

| GSP | Number of DER | DER POC P (MW) |
|---|---|---|
| Bolney | 3 | 35.5 |
| Ninfield | 1 | 59.8 |
| Sellindge | 0 | 0 |
| Canterbury North | 0 | 0 |
| **TOTAL** | **4** | **95.3** |

Calculation of volumes for the active power service are presented at a DER level, since active power losses are expected to be significantly less than the reactive power ones. Furthermore, power factor restrictions in connection agreements do not impose any limitation to the reported active power volumes as operation at unity power factor is always possible for these DERs.

## 8.6 Conclusions

This chapter has presented a summary of the active and reactive power volumes expected to be available for the Power Potential trials, according to the technical submission of interested DER participants. Based on the data currently available and applying some conservative filtering, we are confident that within these sites there is a volume at the DERs level of approximately 113 Mvar of lag capability and 121 Mvar of lead capability.

This translates to around 56 Mvar lag and lead capability at the GSP, a value that could increase if DERs agree to new power factor operational ranges in a modified new connection agreement.

In addition, around 95 MW could also be available for the active power service. These volumes provide the project team confidence that, subject to contract, there is suitable volume to demonstrate the technical viability of the Power Potential solution.

# Appendix A: Published materials

The following materials are available on the Power Potential project website.

**Regional Market Advisory Panel (RMAP)**
Announcement of the Appointment of Dame Fiona Woolf as independent Chair
Terms of Reference
Members
RMAP 22 February 2018 meeting outcomes
RMAP 9 March 2018 meeting outcomes.
RMAP 14 June 2018 meeting outcomes

**Webinars**
21 September 2017 Webinar. Slides and summary document.
29 January 2018 Webinar. Slides and Summary document.
26 March 2018 Webinar. Slides and Transcript.
16 May 2018 Webinar. Slides and Transcript.

**Participant Materials**
DER Framework Agreement. Document.
DER Market Procedures. Document.
Participation payments letter. Document.
DER Technical Requirements for participating Distributed Energy Resources. File.
Technical Characteristics Submission Spreadsheet. Download from project website here.
Power Potential guide to participating: A technical guide to the services for synchronous and non-synchronous DER participants. Link to Download
Technical guidance document. Document.
Historic utilisation charts. Download Spreadsheet from this webpage.
Draft Heads of Terms for DER Framework agreement. Document

# Appendix B: Wave 1 testing and trialling

This appendix sets out the current view of the wave 1 technical trials from the project team, detailing further the principles presented in chapter 7, and may be updated as further detail of the trial design is developed.

The aim of wave 1 is to demonstrate the DERMS technical solution and to validate both the DERMS set-point calculations (according to system conditions or by following direct instructions) and the collective DER's responses to provide transmission support for different operational scenarios. Note that wave 1 will not demonstrate the commercial process implemented into the DERMS as this aspect will be covered in wave 2 of the Power Potential trials.

### B.1 Purposes of technical trialling

The overall purpose of the trialling case studies in wave 1 is to show that:

- DERs can meet the service specification (active and or reactive service, as reported in chapter 8).
- The DERMS issues the correct voltage set-points appropriate to the GB System Operator instruction.
- The DERMS, with DERs, provide the expected reactive power changes and or active power changes at the DER points of connection.
- The DERMS returns DER output to default Mvar operating point if this is required.
- The DERMS, with DERs, provide the expected reactive power changes at the Grid Supply Point (GSP) interface between the distribution and transmission systems.
- The effectiveness of the DERs can be measured at the GSP.
- The modelling and prediction of the DERMS is robust, correctly identifying distribution system limitations on the service utilisation from each DER and the correct prediction of post event capability delivery.
- The DER responding to local voltages does not act to the detriment of UK Power Networks obligations to secure the distribution system.

The different trial case studies anticipated for wave 1 technical validation for reactive and active power services are described next.

### B.2 Reactive power wave 1 technical trials: overview

Reactive power trials in wave 1 are intended to demonstrate the DERMS in a live network environment. Validation of the commercial framework in line with the system operational needs will be covered in wave 2.

The trial processes in wave 1 have been structured in two mainstages wave 1 mandatory technical trials and wave 1 optional technical trials that will validate the reactive power service through DERs, via the DERMS and using PAS, in Power Potential. Before a DER unit can participate in the optional technical trial (and access participation payments) it must complete the mandatory technical trials.

All participants who sign up to the Framework Agreement will be eligible to participate in wave 1 subject to passing the commissioning phase. Wave 1 is planned to commence early in 2019.

The date will be confirmed towards the end of 2018. Precise dates for the transition between Waves will be confirmed closer to the time.

### B.2.1 Reactive Power Wave 1: mandatory technical trials

The cases described in wave 1 mandatory technical trials are aimed to validate the DERMS set-point calculation and DER's responses in isolation before moving into the trial phase where the end-to-end response from DERs via the DERMS to system events and instructions is recorded[21]. The aim of this initial set of trials is to validate that DERs working in the DERMS provide the correct response to simulated 400 kV system voltage changes and that the sensitivity calculations are accurate. Three different initial trials are carried out, both individually and collectively (considering the entire DERs associated to one GSP and/or the entire DER in the project area).

1. Response to signal injection (fast 400 kV voltage change) – Test method 4.
2. Response to signal injection (slow 400 kV voltage change) – Test method 5.
3. Validation of the DERMS sensitivities/effectiveness– Test method 6.

The specific procedures for these trials will be reflected in the description of the specific test methods. These will cover description and purpose of the study, variables to be recorded and assessment criteria. It will be important to record both the DER's response (active power, reactive power, voltage change and response time to set-point changes) and the GSP effect (active power, reactive power and voltage change), amongst other variables. Note that the purpose of the validation of the DERMS sensitivities/effectiveness trial is not to establish these values, but to confirm (when possible) that calculations in the DERMS are accurate.

Mandatory technical trials are expected to run for two weeks during which each DER is expected to be available for two days (one for its individual testing and one for the collective one) during the time windows that are agreed with the project team (initially two windows of two hours). Individual trials will be carried first, followed by collective testing (entire DERs associated to one GSP and/or the entire DER in the project area).

### B.2.2 Reactive Power Wave 1: optional technical trials

The trial scenarios to be covered during the optional technical trials in wave 1 will focus on analysing the DERs and the DERMS responses (end-to-end solution) following different changes in network conditions, without yet introducing the commercial elements of the Power Potential project. This optional wave will be split into a winter and summer phase to allow technical trials to cover different operational scenarios in two seasons. The optional trials will also generate learning outcomes to compare DER's forecasted outputs vs. their expecting operating levels. These trials are driven by system events (unplanned and planned) and not by specific test methods. Four different trial scenarios are expected in this optional wave 1, as described next.

[21] Note that for wave 1 mandatory technical trials, the PAS interface is not expected to be used and simulated voltage variations are envisaged to be simulated at the DERMS level. There is the need to discuss with ZIV (the DERMS developer) to understand how to accommodate this option during the trials. The motivation is that it would be important to validate the DERMS functionality to calculate set-points and working with the DER in a live environment before trialling the end-to-end solution.

1. **Trial 'unplanned event':** the DERMS response to real-system events (interconnector/circuit tripping).
2. **Trial 'Planned step event':** the DERMS response to switching reactive devices and coordinated action of generator transformers.
3. **Trial 'Pre-fault event':** the DERMS response after instruction from the GB System Operator during high voltage scenario.
4. **Trial 'DNO constraint validation'**: a UK Power Networks' thermal/voltage constraint limit is altered to create a hypothetical UK Power Networks constraint.

Wave 1 optional technical trials is thought to be structured over eight weeks (approximately 1,350 hours) of full availability and broken in two stages: one in winter (of six weeks' duration) and one in summer (of two weeks' duration). A longer window is required over winter for the control room engineers to get familiar and trained with the system. Summer trials are required to confirm knowledge from different network conditions. Therefore, wave 1 optional winter trials and optional summer trials are expected to run continuously for a fixed number of weeks, with DERs availability being required 24 hours a day for the full trial periods. During the time in which these trials will run, a DER can declare itself to be available or not for certain windows, and access the participation payments in line to what has been presented in chapter 7.

### B.3 Active power trials: overview

#### Active power wave 1 technical trials

Active power service technical trials are covered in one single wave to validate the DER's response to an active power set-point instruction before moving to business as usual. This trial is mandatary for all potential participants in the active power service. This case study is to be carried by an individual DER and will confirm that DERs working in the DERMS provide the correct response to active power service instructions. One trial is to be carried out for each DER:

1. Response to MW set-point – Test method 7.

This technical validation is expected to run for two weeks during which each DER is expected to be available for one day for its individual testing during the time windows that are agreed with the project team (initially one windows of two hours) and to be carried together with reactive power mandatory trials, if possible.

# Appendix C: Power Factor and Distribution Use of System Charges

**Impact of power factor (PF) ranges on DER's reactive power capability**
Power factor studies were carried out for each site that provided a *Technical Characteristics Submission Spreadsheet* and is energised.

The goal was to understand whether each DER's PF range could be extended beyond prescribed in their connection agreement (typically 0.95 lead and lag) so that they could bid larger volumes of reactive power. One of the examples where it might be valuable is for PV farm which at night has all its rated capacity available (it is equivalent to power factor equal zero).

A methodology was developed to perform the studies, and these were carried out for defined scenarios, using several assumptions. Along with the detailed results, will be shared with each DER. The brief overview the studies' objective, methodology, scenarios and assumptions, along with the findings, which is presented below:

**Assumptions:**

- Power factor studies needed to be carried out for the worst-case scenario to ensure the security of the distribution network.
- Worst-case scenario would occur at a certain combination of conditions on the transmission network (that would trigger DER dispatch) and DER's particular operational mode, that could result in the largest impact on the distribution network (qualitative likelihood of such a case was not considered, as it would be different for different DER technologies)
- The studies would need to be set up separately for two modes: import of reactive power by a DER (lead PF) and export of reactive power into the distribution network by a DER (lag PF).
- Worst-case DER operational scenario was set the same for both lead and lag studies and modelled DER energisation (going from zero to full output) with all DERs connected to the same area of the distribution network simultaneously starting generation to their full capacity.
- Worst-case transmission network operational scenario for the lead study was assumed to occur at the point of GB minimum demand.
- Worst-case transmission network scenario for the lag study was simulated as double-circuit outage on the transmission network near the Grid Supply Point closest to the DER under study.
- Maximum estimated PF range in which DERs would be allowed to operate during provision of reactive power under the conditions defined above, would be the largest value (for lead and lag separately) that would not cause violation of the voltage step-change limit (3%) at the UK Power Networks substation electrically closest to a DER under study.
- It is important to note that though identification of these possible cases with subsequent decision-making process will be implemented in DERMS (i.e. not a customer or UK Power Networks concern), the studies were set up in a deliberately conservative manner to ensure that distribution network would be safeguarded (in the case of DER using wider PF range), as the DERMS is not yet a proven technology.

**Findings:**

- In some of the cases, with the expansion of their PF range, DERs were first reaching (or violating) the voltage step-change limit of 3% (Engineering Recommendation P28[22]) at their own substations (before voltage limit at the UK Power Networks primary was reached). Violation of the step-change voltage at the DER's substation is not endangering the distribution network (and is not necessarily endangering DER equipment). Hence, it is up to the customer to decide which PF range to accept (and then use) based on the detailed studies' results and explanations provided to them.
- The DERs that are connected to the higher voltage levels (and, especially, if they are large by the distribution network standards) significantly impact voltage at their nearest UK Power Networks substations with the change in PF, thus limiting the possibility of PF range extension compared to small DERs deeper embedded into the distribution network.
- For most of the DERs, estimated maximum lead and lag ranges are not symmetrical.
- In most cases lag (export) PF range is narrower than lead (import) range (sometimes significantly).
- If many DERs are connected to the same area (UK Power Networks primary substation), they are 'interacting' (i.e. increasing PF range for one would negatively affect – or prevent from expanding – the range of another/others). Even though there might be many criteria to employ in deciding to whom give a priority (size, likelihood to participate in the trials etc.), it was decided that 'interacting' DERs need to be given a level playing field (i.e. they had been assigned identical PF ranges).

Likelihood of the defined worst-case scenarios occurring simultaneously is different for different DER technologies. For some that are almost constantly in operation (e.g. CHP), the likelihood is very low. For others, such as PV, operation at night would, effectively, equate to energisation. Provision of reactive power at night (time of low demand), especially in the summer, might bring operational conditions closer to the modelled lead worst case scenario. The same would apply to, for example, windfarms and energy storage, if they operate with inverters/ Static Var Compensators (SVC) and the wind is not blowing or the battery is fully discharged, respectively.

If a DER accepts the new PF range, their Connection Agreement would need to be amended. It is estimated that around one work week will be required for UK Power Networks to prepare the amendment.

This new PF range will be active for the trials and will revert to the pre-trials range when they are over. If Power Potential goes into Business as Usual, arrangements would need to made to allow the DER to retain the new Power Factor (subject to new connections in the area). Further information on the results of the power factor studies is shown in chapter 8.

### Impact on DUoS charges arising from participating in Power Potential

Distribution Use of System charges are the distribution network charges and are part of the DER energy bill from their supplier. The charging methodology and rates for all DER in the Power Potential trials area – South Eastern Power Networks (SPN) – are publicly available at the UK Power Networks website.

[22] http://www.energynetworks.org/electricity/engineering/engineering-documents/engineering-documents-overview.html

Two types of charges were highlighted as the ones that might be affected by the reactive power dispatch by a DER:

- Excess capacity charges
- Reactive power charges.

Some qualitative examples on how reactive power dispatch by DER might affect their DUoS charges are provided below.

**Excess capacity charges**

Excess capacity charges are defined as when the customer uses the distribution network capacity (for import and/or export) above what is set in their connection agreement. Import and export are defined by the direction of active power flow.

Export Example (PV Farm, 10 MVA rating, during the day):

- Maximum Export Capacity (MEC): 10 MVA.
- Site is exporting 1 MW and is importing 9.94 Mvar.
- Export capacity: 9.99 MVA = $\sqrt{(1^2 + 9.94^2)}$.

This site is within connection agreement limits, excess capacity charges do not apply.

Import Example (PV Farm, 10 MVA rating, Reactive power at night

- Maximum Import Capacity (MIC): 400 kVA.
- Site is importing 100 kW (e.g. to power inverters) and is importing (or exporting) 9 Mvar.
- Import capacity: 9 MVA > 0.4 MVA.

This site is not within connection agreement limits, excess capacity charges would apply.

No Import or Export Example (PV Farm, 10 MVA rating, Q at night):

- Site is neither importing or exporting P while importing/exporting Q

There is currently no precedent in the DUoS methodology on how to treat this case.

**Reactive power charges**

There are two types of tariffs – CDCM and EDCM. CDCM is a tariff for 11 kV and LV connected customers and it has explicit excess reactive power charges (equations can be found in the charging methodology [reference]). EDCM is the so-called locational tariff for EHV customers (connected to 33 and 132 kV voltage levels). Their charges are based on the Line Loss Factors (LLF). These are multipliers which are used to scale energy consumed or generated to account for **losses** on the distribution networks. They are published every year on the Elexon website[23].

Reactive power dispatch by DERs would affect losses in the distribution network, but exact impact is unknown. It may be positive or negative depending on the variety of factors, for

[23] http://www.energynetworks.org/electricity/engineering/engineering-documents/engineering-documents-overview.html

example distribution network configuration, power flows in the network at the time of dispatch, type of dispatch (import or export of reactive power).

From these examples, given the uncertainty in the procurement and utilisation volumes of reactive power during the trials period, it would be difficult for DERs to forecast or estimate with good degree of accuracy what their DUoS charges triggered by the provision of reactive power service would be. As a result, it poses an uncertainty for DERs that might unpredictably affect their bidding behaviour and, hence, make a negative impact on the subsequent analysis of trials results (it is likely that bids would be higher, but it will be impossible to separate this source of uncertainty and quantify by how much).

Another note, mentioned above, is that there is currently no precedent in the charging methodology on how to treat Q at night service by PVs if they neither import or export active power.

Taking into account considerations listed above, the decision was made not to apply these charges during the trials period, record them as a project learning.

This decision will have an additional benefit to the project. By separating the charges, they can be clearly quantified and then used in the DER bid price and reactive power offers modelling/forecasting (as the charge size would influence bid price and volume offers).

# Appendix D: Responses to formal consultation on draft framework agreement and market procedure

| Who (DER) | *What are your views on the contractual terms required to participate in Power Potential?* |
|---|---|
| DER A | More clarity is needed on how a participant is “deemed to have been available” to provide the reactive power service. |
| DER B | None given |
| DER C | Flexibility in offering variable MVA capacity between waves of the trial would be beneficial. Given a fixed fee during wave 1 and no reactive power utilisation payment this is detrimental to the commercial (and network) gains from a larger MVA offering. Being able to ‘step up’ available MVA from wave 1 to wave 2 would be advantageous, for example a +/- 5MVA offering during wave 1 from our 20MVA STATCOM would limit the operational use which we wouldn’t be compensated for. Once we’re rightly credited for MVA delivery, full capacity utilisation would be offered.<br>GDUoS exceedance exposure charges during wave 1 should be explicitly defined as being recoverable as earlier communicated.<br>It isn’t clear that the £5 million liability does not exclude any 3rd party damage following the change in operation of windfarm as a result of UKPN instructed actions. |
| DER D | We believe the terms are suitable to participate in the Power Potential trial. However, these terms should be subject to review after Wave 1 to account for any unforeseen factors and/or costs associated with the DERMS and associated IT infrastructure. |

| Who (DER) | *What are your views on the proposed Power Potential payment structure?* |
|---|---|
| DER A | It is mentioned that reactive power utilization is the absolute difference between baseline and actual injection/absorption during a half hour period. Will injection and absorption be measured separately and account in the total utilization volume? |
| DER B | None given |
| DER C | Would prefer a longer period than 5 business days to challenge statement. |
| DER D | We think the proposed payment structure is suitable during Waves 2 and 3. Clarification on the Wave 1 payment structure would be useful. Specifically, the following:<br>1. What is the payment for the reactive power service during the ‘Wave 1 Mandatory Technical Trial’?<br>2. How was the £18,000-£20,000 participation payment range determined for the ‘Wave 1 Optional Trial?’ |

| **Who (DER)** | *What would an appropriate £/MWh payment be for the mandatory technical trials for the active power service?* |
|---|---|
| DER A | The payment must be agreed with each participant, as the cost structure for each participant may differ. |
| DER B | None given |
| DER C | Compensated for loss of renewable certificate revenue and exposure to imbalance charges as a minimum. I'm assuming we would be exposed to non-delivery charges as not ABSVD applicable unlike BM bids/offers. |
| DER D | This would depend on the site/operational considerations, until specific assets have been finalised it would be difficult to give an appropriate figure. Our current forecast sits between £100- 300/MWh dependent on varying factors. |

| **Who (DER)** | *Any further comments you would like to express?* |
|---|---|
| DER A | Is the due date for the confirmation of the project implementation to be included in the final framework agreement? |
| DER B | 3.3.1.2 first paragraph indicates that DER availability is required 24 hours a day. We anticipate providing reactive power during periods when there is no active power generation from the solar sites (Q at night). To calculate Availability Thresholds will de-rating be based on a baseline of 24 hours per day or a baseline of declared day-ahead availability?<br><br>3.3.1.3 first paragraph indicates a maximum Participation Payment of £20,000. As stated in section 2.1, the intention of this payment is to allow participant to recover most of their costs. £20,000 is considerable less than the anticipated costs which we expect to face in preparing our DER sites to participate in the Power Potential trial. Q at night from a solar site could prove a valuable as part of the trial which will not be possible at this price. Will the maximum payment be revised up to cover a greater proportion of costs?<br><br>3.3.1.3 final paragraph indicates that there is possibility that the trial may not take place. This possibility introduces a risk that there may not be any commercial benefit more than £15,000 (80% of maximum Participation Payment). Since £15,000 does not cover the costs we will incur we will require confirmation on the decision on whether to proceed with the trial before making any investment.<br><br>3.3.2.1 final paragraph indicates that the market will run for a minimum of 1800 hours and longer should the budget allow. Could you provide an indication to the total value of this market (i.e. budget assigned to service payments)? This will help us understand the potential revenue that could be received in this part of the trial.<br><br>3.3.3. Wave 3 will commence if National Grid determine that the service is competitive with options already available. Can you provide information for what price level would be considered competitive by National Grid including the costs associated with derating active power or maintaining generation out of merit? This will help make a forecast of any expected future revenues. |
| DER C | Framework termination/extension – 3.2 should provide opportunity for DER to contribute to expiry date agreement extension, 12.1.2 extension should also be in agreement with DERs.<br>Conduct investigations – 10.3, whilst acknowledged in note 3 'some limitations' should be more clearly defined. Exactly what equipment/site investigative work required could have more clarity |
| DER D | What is the expected process and cost for installing the LAN between the DERs and UKPN and which party will be responsible for absorbing the cost? |