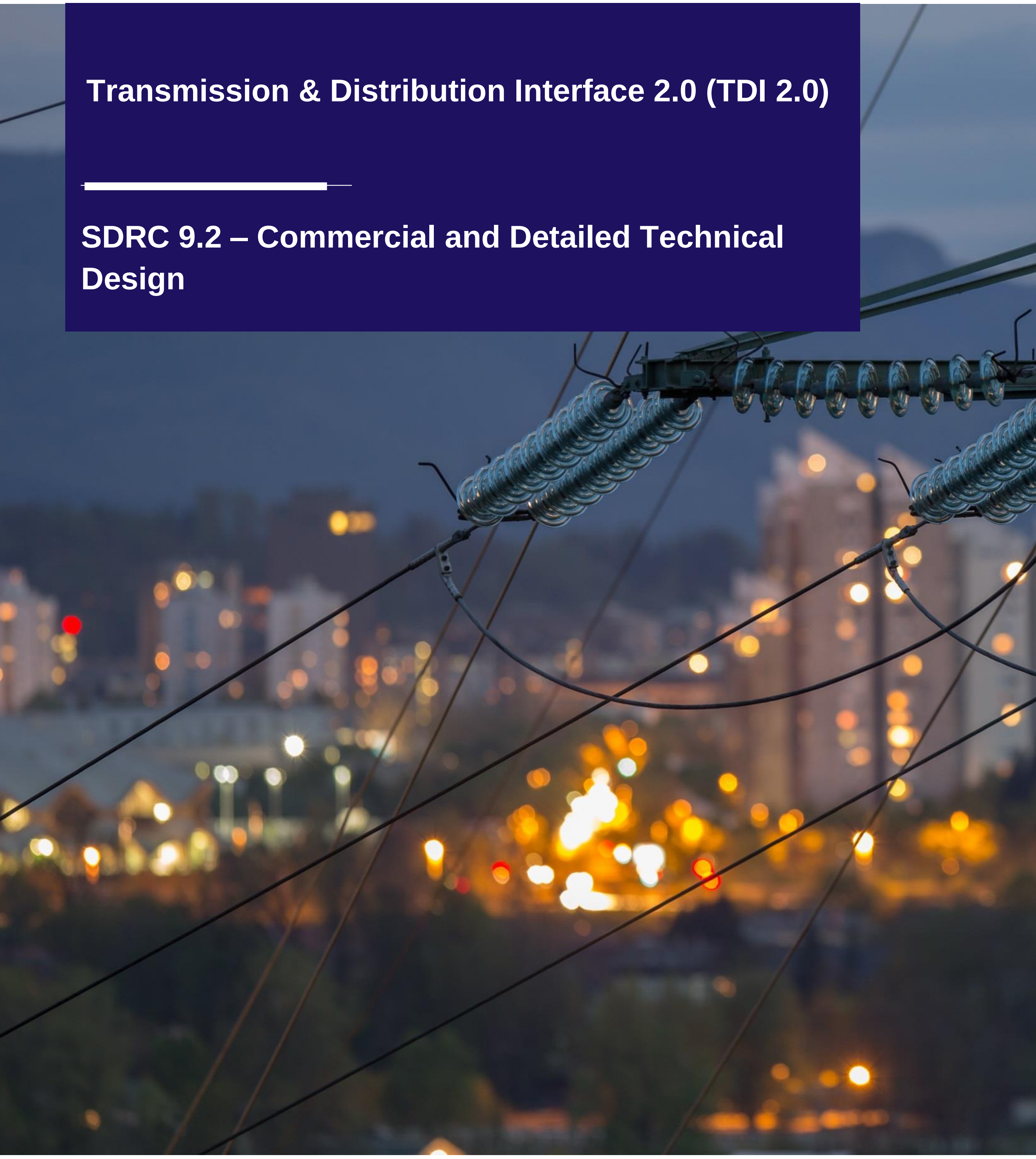
Transmission & Distribution Interface 2.0 (TDI 2.0)

SDRC 9.2 – Commercial and Detailed Technical Design



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Definition of Terms

Acronym	Text
ANM	Active Network Management
API	Application Program Interface
AOMS	Automated Outage Management System
CIGRE	International Council on Large Electrical Systems
CIM	Common Information Model
CPU	Central Processing Unit
CSV	Comma Separated Values
DB	Data Base
DER	Distributed Energy Resources
DERM	Distributed Energy Resources Management
DERMS	Distributed Energy Resources Management System
DMS	Distribution Management System
DNO	Distribution Network Operator
DSO	Distribution System Operator
EBS	Electricity Balancing Services
EHV	Extra High Voltage
EMS	Energy Management System
ENA	Energy Network Association
ENCC	Electricity National Control Centre
ESB	Enterprise Service Bus
EWiRE	Entrepreneurial Women in Renewable Energy
FC	Fibre Cards
ENTSO-E	European Network of Transmission System Operators for Electricity
FEP	Front End Processors
GB	Great Britain
GE	General Electric
GSP	Grid Supply Point
GW	GigaWatt
HTTP	Hypertext Transfer Protocol
HTTPS	Secured Hypertext Transfer Protocol

Acronym	Text
ICT	Information Communication Technology
ICCP	Inter-Control Centre Communications Protocol
IEC	International Electrotechnical Commission
IET	Institution of Engineering and Technology
IPS	Secure Internet Protocol
IPSA	Software tool developed specifically for Power Systems
ISO	International Standards Organisation
IT	Information Technology
JSON	JavaScript Object Notation
KASM	Kent Active System Management
LCNI	Low Carbon Network Innovation
NCE	Network Capability Engineer
NoSQL	Non SQL or Non Relational database
MongoDB	Open-source cross-platform document-oriented database
Mvar	Mega Volt Ampere Reactive
Mvarh	Mega Volt Ampere Reactive per hour
MVP	Minimum Viable Product
MW	Mega Watt
MWh	Mega Watt per hour
NAP	Network Access Planning
NG	National Grid
NGET	National Grid Electricity Transmission
NMM	Network Model Manager
ODATA	Open Data Protocol
OPF	Optimal Power Flow
OS	Operating System
OTSE	Operate The System Engineer
P	Active Power in MegaWatts
PAS	Platform for Ancillary Services
PF	Power Factor
PPA	Power Purchasing Agreement
Q	Reactive Power in MegaVars
RAM	Random Access Memory
RDP	Regional Development Programmes

Acronym	Text
RHEL	Red Hat Enterprise Linux
RMAP	Regional Market Advisory Panel
RTU	Remote Terminal Unit
SAS	Serial Attached SCSI (Small Computer System Interface)
SCADA	Supervisory Control and Data Acquisition
SDRC	Successful Delivery Reward Criterion
SQSS	Security and Quality of Supply Standard
STOR	Short Time Operating Reserve
TDI	Transmission and Distribution Interface
TNCC	Transmission Network Control Centre
UK	United Kingdom
UKPN	UK Power Networks
UML	Unified Modelling Language
VARs	Volt Ampere Reactive
VM	Virtual Machine
WAN	Wide Area Network
XML	Extensible Markup Language

1. Executive Summary

The Transmission and Distribution Interface 2.0 (TDI 2.0) also known as Power Potential project aims to create market access for DER to participate in ancillary service provision to National Grid via UK Power Networks' coordination. It is envisaged that the services provided by DER will alleviate both transmission constraints while considering constraints in the distribution network unlocking whole systems benefits such as additional network capacity and operational cost savings to customers. The project's approach will be trialled on the South East coast network where a significant uptake of DER has meant that technical constraints in the area are now having an effect.

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 National Grid faces in this area have been triggered by the previous growth in low carbon technologies connecting to the distribution network and can be summarised as:

- High voltage in periods of low demand;
- Low voltage under certain fault conditions; and
- Thermal constraints during the outage season.

These constraints have led to the following challenges in the area:

- Fewer low carbon technologies can connect to the network;
- A high risk of operational issues in the network which could affect customers; and
- A high costs of managing transmission constraints.

In order to provide voltage support in the area, increasing reactive compensation is needed. DER connected to the distribution network have the potential to provide reactive and active power services to the transmission system. TDI 2.0 seeks to give National Grid access to resources connected to UK Power Networks' South Eastern network to provide additional tools for managing voltage and thermal transmission constraints.

The TDI 2.0 project will include the creation of a regional reactive power market which will be the first of its kind in Great Britain and will help defer network reinforcement needs in the transmission system.

The project will help enable more low carbon resources to connect in the South East and give new and existing DER the opportunity of providing services to National Grid and accessing additional revenue streams. Services procured from DER will be coordinated such that the operation of the distribution and transmission networks are kept within operational limits and constraints are not breached. When deployed, the TDI 2.0 method is expected to deliver:

- 3,720 MW of additional generation in the area by 2050
- Savings of £412m for GB consumers by 2050

1.1 TDI 2.0 project approach

The TDI 2.0 project is structured into the following key deliverables:

- A commercial framework using market forces to create new services provided from DER to National Grid via UK Power Networks.
- A market solution known as Distributed Energy Resources Management System (DERMS) to support technical and commercial optimisation and dispatch. It includes gathering bids from

DER and presenting an optimised view of the services to National Grid split by GSP. The DERMS will be installed in UK Power Networks control room.

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

- Gather commercial availability, capability and costs from each DER;
- Run power flow assessments to calculate possible availability of each service at the GSP. Once the assessment is complete, a range of service availability and costs will be presented to National Grid as intra-day availability (or 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, National Grid the system operator, will decide the level of services to be procured; and
- 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.

1.2 Report Structure

This report (representing the project SDRC 9.2) focuses on the detail level design of the project and summarises the desired functionality as well as some of the design decisions to achieve it. The key evidence against report sections is summarised in the following topics:

- Stakeholder consultation findings;
- Functional Specification Documents;
- Finalised Commercial Framework; and
- Detailed Business Processes.

1.2.1 Stakeholder consultation findings

The project team has shared its latest thinking and 'minded to' approach for operating the TDI 2.0 solution with interested parties through one-to-one meetings, a webinar, industry conferences and publishing materials on the project website. 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 value of historic reactive power, establishing requirements of the DERMS and working with academic partners. This is detailed below in Chapter 3.

1.2.2 Functional Specification Documents

DERMS is the software solution designed by the project in conjunction with ZIV Automation the software supplier. TDI 2.0 is centred around DERMS, a data-intensive application, and employs automation of processes, including network monitoring and DER dispatch. The detailed design for DERMS is described in Chapter 4 where the Data architecture, Technology architecture, Solution Options and the Security Architecture is covered in detail.

1.2.3 Finalised Commercial Framework

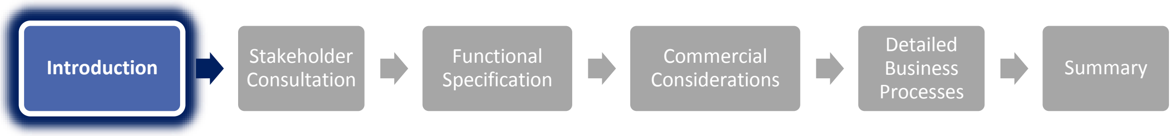
The project has developed both technical and commercial non-built solutions to address transmission constraints and release capacity to connect more DER. As one of the main goals is to create a route to market for DER to provide ancillary services, a commercial framework has been developed in parallel to the technical functionalities to enable the services to be offered to National Grid via UK Power Networks. Chapter 5 describes the detail commercial design based on the engagement with DER to date. It highlights the market design approach to create the commercial services, highlights roles and responsibilities between parties and summarises key considerations regarding contract design, value stacking and DER engagement.

1.2.4 Detailed business processes

The detailed business processes are described in Chapter 6. It details the internal business processes that will require change to operate the new solution. The affected National Grid processes are identified and their impact summarised. Electricity Network Control Centre (ENCC) will be the area which is mainly impacted and will be responsible for instructing successfully secured DERs to satisfy the active and/or reactive power requirements. In UK Power Networks, a new function within the existing control room scope will be required to coordinate the DER participation. This is a new function called DER Scheduling team. This new function will be responsible for closely working with the New Connections teams and existing DER to manage and maintain a healthy portfolio of DER to effectively sustain the TDI 2.0 day to day operation.

Both organisations have yet to establish these business changes, which are envisaged to be activated during the TDI 2.0 trial phase.

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 in 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 Richborough, 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, as well as plans for two more in the years to come.

The South East Coast network includes 2GW of peak demand and 5.5GW 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 future).
  - **ELECLINK HVDC** (VSC): to be connected at Sellindge substation (expected in 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 150kV.

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. 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; and
- Thermal capacity: potentially leading to generation curtailment during the summer maintenance season.

These constraints are most prominent when a fault occurs on the route between Canterbury and Kemsley, which 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 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 regional challenges:

- Fewer low carbon technologies can connect in the area;
- High risk of operational issues and their consequences; and
- High costs of managing transmission constraints.

2.1.2 Our approach

Reactive compensation is needed in order to provide voltage support in the area. DER connected to the distribution network have the potential to provide reactive and active power services to the system.

TDI 2.0 seeks to give National Grid access to resources connected in UK Power Networks South Eastern network to provide it with additional tools for managing voltage transmission constraints. To achieve this, the project will develop technical and commercial solutions to maximise the use of DER to manage transmission voltage and thermal constraints. The GSPs considered in this project are Canterbury, Sellindge, Ninfield, Bolney and Richborough.

The project will use DERMS software installed in UK Power Networks' control room which would enable DER to offer dynamic reactive power services to National Grid and offer flexibility for active power re-dispatch to manage transmission constraints. The services offered by DER to the network will be coordinated by UK Power Networks and is a step towards transitioning from a Distribution Network Operator to a Distribution System Operator

It is estimated that TDI 2.0 will be able to create financial benefits for consumers by achieving cumulative savings in the area from £1m by 2020 to £29m by 2050 as a result of deferred investment in the transmission network. It will also create additional network capacity to enable UK Power Networks to connect a further 3,720 MW of distributed generation in the area by 2050.

2.1.3 Project timeline

The project will be delivered in the following phases:

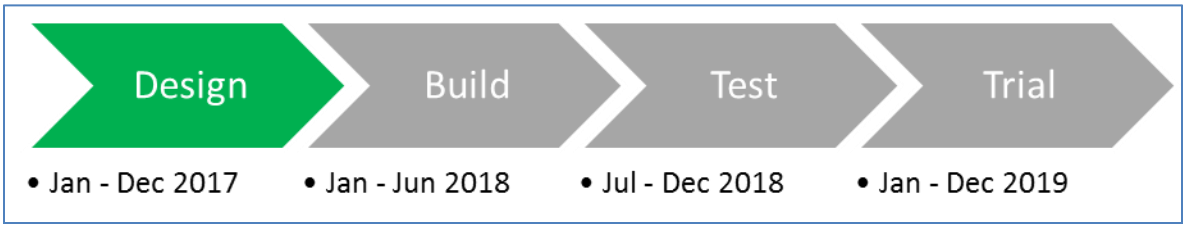


Figure 1 – Project timeline

2.2 Purpose of document

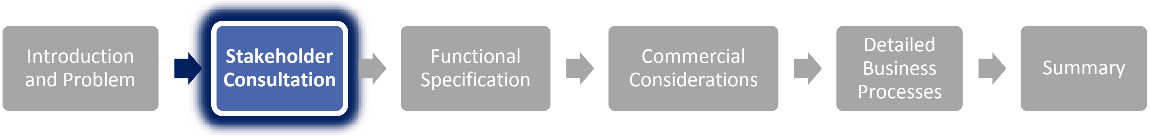
The purpose of the document is to describe the project's detail level design. The document will present the main project functionality, commercial framework and business process to change for TDI 2.0 solution. The document also covers learnings form external and internal consultation with TDI 2.0 stakeholders.

Key evidence criteria of SDRC 9.2 is presented in Table 1 – Key evidence criteria of SDRC 9.2 and corresponding sections of the document

Criteria	Evidence	Section
Commercial and Detailed Technical Design – the agreed detailed technical design (Partner/s, National Grid, UKPN and Customers) and Commercial Framework for the trial	• Stakeholder consultation findings	Chapter 3
	• Functional Specification Documents	Chapter 4
	• Finalised Commercial Framework	Chapter 5
	• Detailed Business Processes	Chapter 6

Table 1 – Key evidence criteria of SDRC 9.2 and corresponding sections of the document

3. Stakeholder Consultation and Findings



3.1 Background

As the technical and commercial TDI 2.0 solution progresses through design, build, test and trials, the project team are engaging with stakeholders to share progress and seek feedback to refine both the solution and also the information provided to interested parties.

This Chapter 3 presents the details of stakeholder consultation undertaken during the SDRC 9.2 period and the findings of this activity (which are in section 3.3.3).

3.2 Scope of Stakeholder consultation and findings during SDRC 9.2

During 2017, the project team has continued to broaden and deepen engagement with key stakeholders building upon the detail presented in SDRC 9.1.

As the technical and commercial design of the TDI 2.0 service has developed during this detailed design phase, the project team has shared its latest thinking and 'minded to' approach for operating the TDI 2.0 solution with interested parties through one-to-one meetings, a webinar, industry conferences and publishing materials on both the project website[1] and through a blog on the Energy Networks Association (ENA) website[2].

Progress has been made, and is detailed below, 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 value of historic reactive power, establishing requirements of the DERMS and working with academic partners.

This stakeholder consultation has both provided early signals to potential service providers DER within the project area and also aggregators interested in bringing together DER) and also valuable feedback to inform the detailed design and the information that the project provides to help encourage participation.

During this period, key channels for stakeholder consultation have included:

- Direct engagement with seven DER within the project's geographic area. This includes both existing energised DER and prospective DER with accepted connections.

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

[2] http://www.energynetworks.org/blog/2017/11/14/open-networks-monthly-blog-delivering-on-our-power-potential/

Photo 1: The project's commercial workstream team has undertaken face-to-face meetings with DER and aggregators (here with Reactive Technologies)

- Webinars – to present progress to date and the 'minded to' approach for undertaking the TDI 2.0 trials.
- The ENA Open Networks Project and its workstreams have provided a key channel for engaging other Network Licensees (in addition to the ENA's Low Carbon Network Innovation Conference).
- A project blog posting on the ENA website[3]:

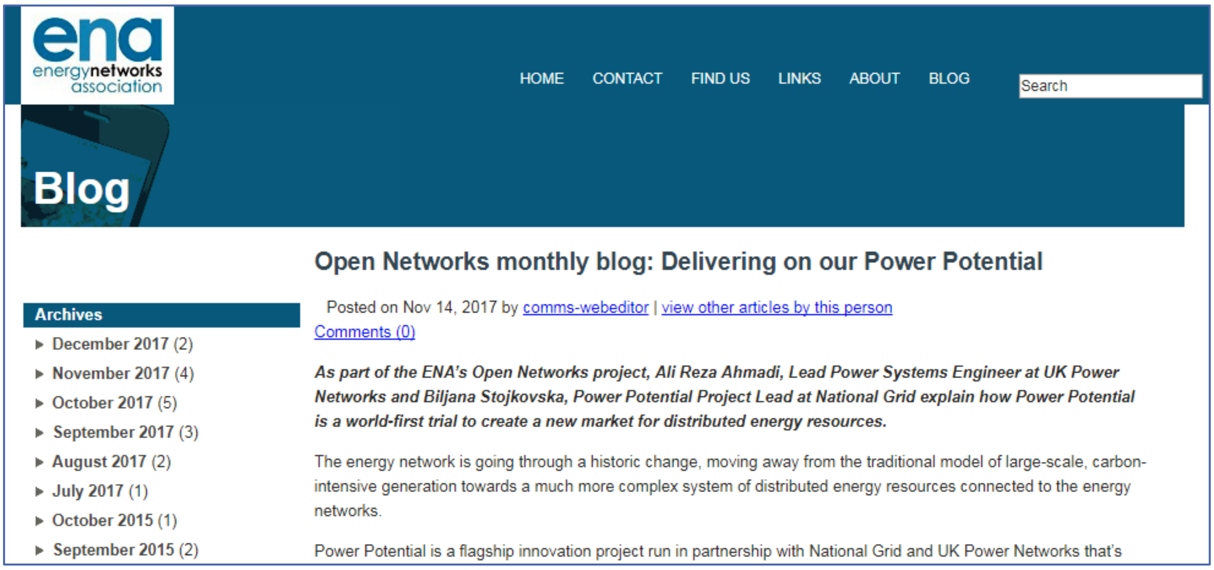


Photo 2: The project's blog on ENA's website

[3] http://www.energynetworks.org/blog/2017/11/14/open-networks-monthly-blog-delivering-on-our-power-potential/

- Industry conferences, workshops and meetings with professionals throughout the electricity system value chain as summarised in Table 2.
- Project Website – the TDI 2.0 project website[4] provides details on the projects objectives, latest progress and documents for download. This includes published project materials (e.g. the Guide to Participating, September 2017) as downloadable reports on the project website as well as sharing directly with webinars participants and in direct communications with interested parties.

3.3 Engagement with Distributed Energy Resources (DER)

3.3.1 Engagement plan

A key element of delivering a successful TDI 2.0 trial is recruiting a diverse range of DER participants in sufficient volumes. In order to achieve this successful outcome, and to approach DER recruitment in an open, fair and coordinated way, an engagement plan was developed. Engagement activities so far taken place and the plan for the future are summarised in Table 2.

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

Communication Activities	Who	Channel	Date
DER participant workshop **Participants will have the opportunity to share their general feedback, as well as being asked specific technical and commercial questions**	Cross–section of aggregators and directly connected customers who expressed interest in the project. 17 attendees to enable open discussion.	Workshop	9 May 2017
Webinar **Communicate latest updates to industry and offer opportunity to ask questions and provide input**	All interested DER and aggregators (and other parties)	Webinar (with slides and webinar summary published on the project's website[5])	21 September 2017
One–to–one engagement **Discussions around service provision and bespoke capabilities/requirements of participants (which may be sensitive/confidential)** **Reaching out proactively to all DER within the project area with a capacity of at least 1MW.**	DER participants in the South East coast area	Face to face	Summer/Autumn 2017 and ongoing
Publication of Guide to Participation on project website	All interested DER and aggregators (and other parties)	Project website	September 2017
2nd DER webinar to: **Update on commercial proposition (firmer requirement approach)** **Share draft Head of Terms agreement** **Invite expressions of interest**	All interested DER and aggregators (and other parties)	Webinar (with slides and webinar summary published on the project's website[6])	January 2018

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

Communication Activities	Who	Channel	Date
Presentations and project team participation at industry meetings and conferences, including the following examples.	All interested DER and aggregators (and other parties)	Power Responsive Conference CIGRE & IET event EWiRE "smart decentralised system" event LCNI Conference & Exhibition Flexibility Forum	27 June 2017 18 October 2017 16 November 2017 6-7 December 2017 February 2018
3rd DER webinar to: **Update on commercial proposition & respond to feedback following expressions of interest**	All interested DER and aggregators (and other parties)	Webinar (with slides and webinar summary published on the project's website[7])	April 2018
Contracts signed with participating DER before the project's technology solution testing takes place	Participating DER	Direct engagement with project team and contractual documentation	May – June 2018

Table 2 - Engagement plan with project participants

3.3.2 DER Consultation

The project team has consulted prospective participants on a range of technical parameters to inform the detailed design of the TDI 2.0 solution, the commercial framework and what information the project will need to provide to help support DERs in their consideration to participate in the project. Consultation findings are used to brief the Regional Market Advisory Panel and the Project Steering Committee to inform the overall strategic direction of the project.

The Project Team has consulted DER on detailed considerations, including:

- Is the site's P (real power export/import) independent of Q (reactive power import/export)?
- Is the site's P (real power export/import) independent of Q (reactive power import/export)?
- How long does it take (milliseconds) to switch from PF mode to Voltage [Droop] mode? (if applicable)
- Minimum/Maximum active power (P) export
- Minimum/Maximum reactive power (Q) export
- What are the DER's timescales for making any changes to systems to meet the technical/commercial criteria?
- Metering capabilities and granularity of recorded data

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

- What changes will the DER need to consider in order to be able to participate?
- How could the project help with this?
- What would give the DER more certainty to participate?
- Whether availability and arming requirements and incentives should be combined and if this preference varies by technology type.

3.3.3 DER engagement findings

Key findings from DER consultation have demonstrated high levels of interest in the TDI 2.0 project and positive benefits of early consultation for both the project team and the prospective TDI 2.0 service providers (DER and Aggregators). This has identified themes where potential participants are seeking more information to evaluate their commercial consideration of the case for bidding to participate in the trials.

In addition to organisation and asset specific discussions, a number of common themes emerged from the latest round of DER engagement, including:

- The frequency, duration, scale and value of service that will be required by the transmission system at the four GSPs within the study area. Stakeholders valued this information to be able to develop their cost benefit analysis of participation.
- Clarification of set-point adjustments and communications required to instruct the different services, in order to evaluate any upgrade on existing control systems.
- The ease of forecasting accurately the volume of active and reactive power that would be available, particularly for active power (MW) – depending on technology type, there were different preferences on how close to real time availability should be declared. Those with assets with more variable output favour closer to real time declaration.
- Metering requirements for verification of service delivery – it is important to ensure metering costs are not prohibitive to participation. There is a balance to be struck on the degree of granularity required that demonstrates delivery of the service without deterring participation.
- Interaction with other services or agreements – it is necessary to consider the impact of participation in TDI 2.0 on existing Balancing Services contracts and PPAs. The interaction with Balancing Services is being addressed through the project and will be reflected in contract terms.
- The distinction between availability instructions and arming instructions for reactive power (Mvars) – depending on technology type and fuel source/cost, there were different views on whether availability instructions should lead to assets being armed, or whether this should occur at a later stage in the dispatch process.
- Payment structures and the balance between participation, availability and utilisation payments.
- Whether compensation would be provided to cover the cost of upgrading assets to be capable of providing the services required.
- Requests for additional information and reassurance to increase confidence in the commercial opportunity that participating in providing TDI 2.0 services will create.
- The impact of the trial's proposed day ahead procurement approach for solar providers, where at this period of pre-delivery bidding may have considerable uncertainty about levels of irradiance.

3.3.4 Acting on Engagement findings

The project team is actively incorporating the feedback and insight from DER engagement as the project refines the project guidance and the resources to inform the commercial proposition for participants.

Engagement will continue to ensure that the quantity, scale and diversity of trial participants is great enough to achieve the project objectives. Next steps in engagement include maintaining the interest of DER that have already expressed interest and continuing dialogue as the project develops and the DER develop their commercial case to participate. At the same time the project team will be reaching out proactively to all DER above 1MW capacity within the study area and take additional actions to engage DER that are located in geographic locations that technical studies have identified are expected to be most effective at providing services to the transmission system at the four grid supply points within the study area.

Engagement with intermediaries such as trade associations representing DER will also as another channel to promote the opportunities that the project is developing and to reach more interested parties.

Two further webinars are being scheduled to provide further details to interested parties and these will present updates on the commercial proposition, reflecting the feedback received. The webinars will also share the proposed Heads of Terms Agreement and invite expressions of interest to participate in the project early in 2018 before moving to contract agreement and signing in May and June 2018. Other further details of engagement with DER, their representatives and aggregators during the period are reported within the Chapter 5 of this report.

3.4 Regional Market Advisory Panel

A Regional Market Advisory Panel (RMAP) is being established to provide a formal channel for the project to engage and consult with key stakeholder groups including Ofgem, DER and their representatives.

The RMAP will be overseen by an independent chair, to be appointed in early 2018. Terms of Reference have been developed for agreement with the RMAP in these initial meetings.

The Steering Committee oversaw and reviewed a short list of potential persons and identified key attributes to make the role a success. Following this a proposed approached and engagement plan is underway to confirm this appointment.

3.5 Engagement with Network Licensees

In addition to the ENA's Low Carbon Network Innovation Conference, the ENA Open Networks Project provides the key channel for engaging other Network Licensees. The TDI 2.0 team have been actively engaging with the Open Networks Project team.

In addition the project has had the opportunity to write a blog[8] on the ENA website. The post went live on 14 November and was shared using National Grid's social media channels, the ENA LinkedIn profile and UK Power Network's Twitter account. This was a further opportunity to reach out to Network Licensees.

[8] http://www.energynetworks.org/blog/2017/11/14/open-networks-monthly-blog-delivering-on-our-power-potential/

UK PowerNetworksNews @UKPNnews · Nov 16

We're working with @nationalgriduk on Power Potential, a world-first trial to create a new market for distributed energy resources. Read about how this project is set to change our industry energynetworks.org/blog/2017/11/1...

Photo 3: UK Power Networks' Twitter account promoting the project's ENA blog article

3.6 Internal engagement

Consultation with relevant internal stakeholders within National Grid and UK Power Networks has continued throughout the detailed design phase to share progress and identify and address potential issues and risks. Collaboratively the project identified the key business users from the areas that will be impacted by solution and defined the following:

- Finalised the requirements definitions
- Helping the project make design decisions to satisfy the requirements (See Sections 4, 5 and 6)
- Agreeing the minimum viable product that will enable the trials phase (See Sections 4 and 5)
- Define the data required for the project and helping the project team to understand the complexity of the networks models (See section 4)
- User interface definitions (See section 4)

Within UK Power Networks the following teams have been consulted: Network Control Centre, New Connections, Outage Planning and Infrastructure Planning, Asset Management and Strategy & Regulation.

3.7 Other engagement

The project team have been actively involved in presenting at external conferences and visiting sites with similar implementation, all list below in this paragraph. The findings from these external engagements has resulted into assessing any lessons learnt and taking on board feedback from the external parties on how the solution could be useful in the industry. These have been incorporated into design of the solution where applicable. The following is a list of external engagements:

- **Low Carbon Network Innovation conference, 6&7 December 2017** – a collaborative presentation on the project by Biljana Stojkovska (National Grid) and Ali Reza Ahmadi (UK Power Networks). The breakout session on “Active Network and Demand Side Response” was delivered with great interest from the attendees, this has led to additional post conference engagements. An interactive demonstration and introductory video were displayed on both National Grid and UK Power Networks’ exhibition stands, supported by the project team, demonstrating the TDI 2.0 solution in a number of scenarios from both the transmission and distribution network perspectives.

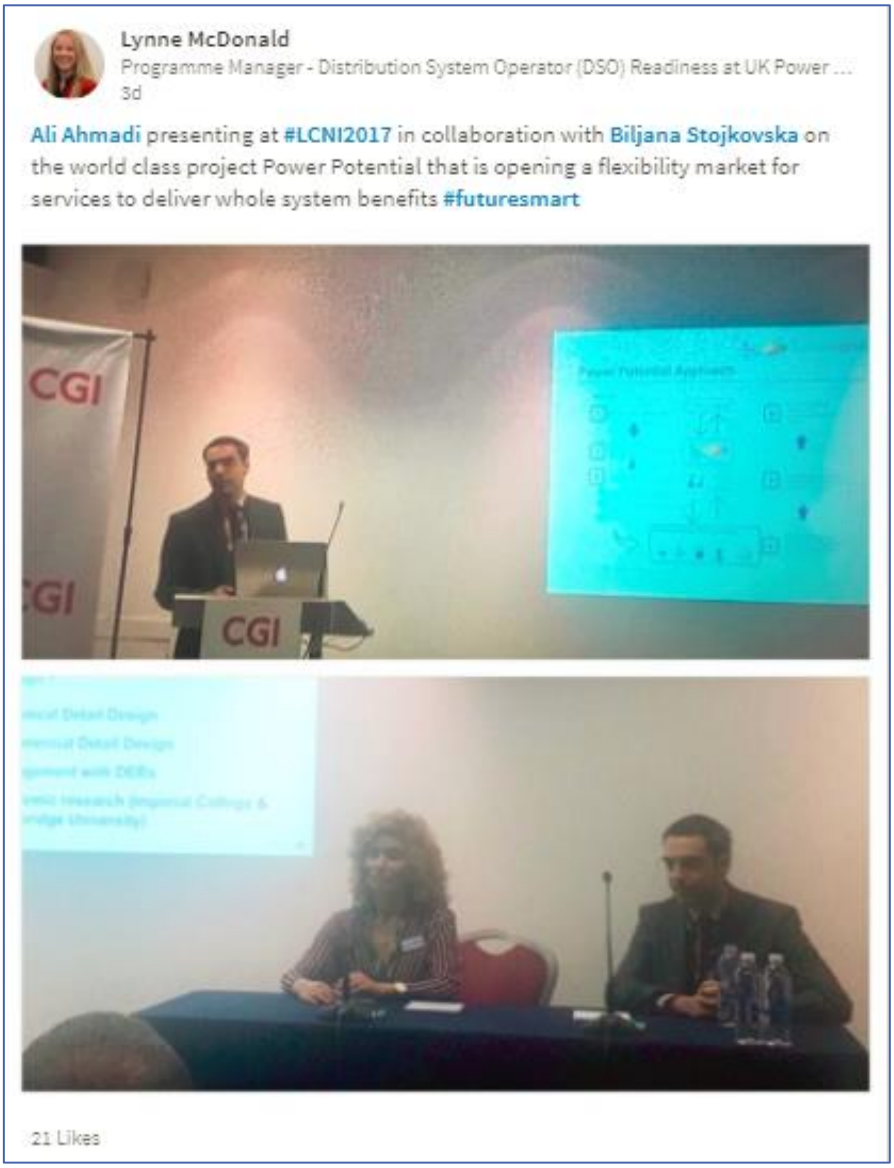


Photo 4: LinkedIn post of the project being presented at the LCNI conference, 6 December 2017, Telford

- **Visit to Swiss Grid and AXPO Power AG, Switzerland, 16-17 October 2017** – to investigate approaches to reactive power across the transmission and distribution system boundary within Switzerland and to present the TDI 2.0 solution to this challenge.

Photo 5: Swiss Grid visit joint UK Power Networks and National Grid

- **CIGRE & IET event: *Solving Electricity Network Challenges*, Birmingham, 18 October** – presentation on TDI 2.0 by project lead Biljana Stojkovska to an audience of over 60 technical subject matter experts.

Photo 6: Project Lead Biljana Stojkovska presenting at the CIGRE & IET event

- **EWiRE (Entrepreneurial Women in Renewables), 16 November 2017** – panel discussion on “a smart decentralised system” included project lead Biljana Stojkovska.
- **Power Responsive Conference 2017, Emirates Stadium, London, 27 June 2017,** – presentation by Sotiris Georgiopoulos, Head of Smart Grid Development and TDI 2.0 Steering Committee member at UK Power Networks to an audience of several hundred professionals across the electricity system value chain as summarised in the post-event summary on the Power Responsive website[9]:

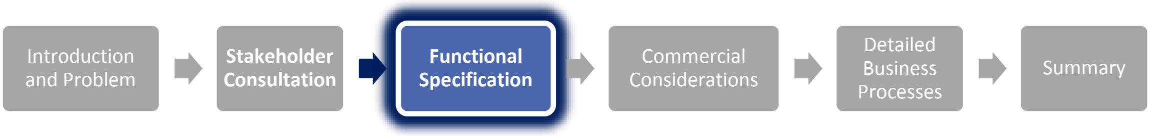
Sotiris Georgiopoulos (UKPN) gave an overview of the Power Potential (TDI 2.0) project, which is exploring the transmission and distribution interface. It focuses on the creation new opportunities in the South East of England for DER connected to the distribution network to provide dynamic voltage support and constraint management services to the System Operator via UK Power Networks. There is potential for 3720 MW of additional generation in the area and savings of £412m for UK consumers by 2050. A framework agreement will be developed to cover operational and commercial requirements of parties.

power responsive 8 nationalgrid

Photo 7: Extract from Power Responsive Conference Summary, 27th June 2017, London

[9] http://powerresponsive.com/wp-content/uploads/2017/07/Power-Responsive-Conference-Summary-27th-June-2017-Final.pdf

4. Functional Specification Documents



4.1 Introduction

The objective of this chapter is to present the detailed design of the Distributed Energy Resources Management System (DERMS) and its position in the wider technical context of Power Potential. This work builds on the Power Potential High-level design presented in SDRC 9.1 – 'Technical High-level design[10]. In order to highlight the continuity of the work, all design decisions, choices and any changes made at the Detailed Design stage are referenced back to the corresponding sections of SDRC 9.1[11]. In the case of the choices and changes, the rationale behind these decisions has been provided.

The Chapter is structured as follows:

- Section 4.2 provides the list of changes in design decisions and considerations made at the detailed design stage of the project with rationale behind these changes.
- Section 4.3 summarises key aspects of the DERMS functionality.
- Section 4.4 presents DERMS logical architecture and ties the DERMS functionalities to the application components.
- Section 4.5 maps all data sources along with the data exchange flows in the project facilitating DERMS operation.
- Section 4.6 covers communication links and interfaces necessary for the integration of DERMS into the project's partners existing IT infrastructures.
- Section 4.7 expands on the Technology Architecture, presented in the SDRC 9.1[12] and provides a summary of the hardware, software and virtual resources required to deploy DERMS.
- Finally, Section 4.8 highlights security arrangements necessary for the safe operation of the solution in conjunction with UK Power Networks' and National Grid's critical systems, and the communication with these systems.

4.2 Changes from the High-Level Design

Detailed design of DERMS functionalities builds on the high-level design and design considerations presented in the SDRC 9.1[13]. However, with the ongoing technical and commercial work some changes were introduced in comparison to the high-level design. Changes in the design decisions regarding DERMS functionality along with the rationale behind them are summarised in Table 3

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

[11] Ibid

[12] Ibid

[13] Ibid

High-level design (SDRC 9.1) Section	Decision/consideration	Detailed design (SDRC 9.2)	Rationale
3.3.	Three commercial services: 1. Reactive power for High Volts 2. Reactive power for Low Volts 3. Active Power for thermal constraints	Services 1 and 2 are combined into one: Reactive Power Service	All DERs will be 'armed' (given voltage set-points) and will react to the change in voltage at their point of connection (or to DERMS instruction) in less than 1 second. Therefore, at the grid supply point level there is no difference between the services (and their price)
3.4.2, 5.3.1, 5.3.4	Optimal Power Flow (OPF)	Will be implemented as heuristic[14] optimisation considering distribution constraints	DERMS vendor design decision
3.4.2	Day-Ahead module described as Forecaster and OPF	Is split into Forecaster and 'Future Availability' (both on logical level and as software components)	DERMS vendor design decision. Methodology remains the same (forecasted load and generation are used in load flow and optimisation)
3.3.	DERMS would freeze then optimise transformer taps	Control and optimisation of transformer taps is excluded from the current solution as it is too complex to design. It was agreed by the project team that this feature is not required to conduct trials and hence not in the MVP.	
4.1.2.1	Asset parameters from PowerFactory	All network model data will be supplied to DERMS by PowerOn (Sections 4.5.3 and 4.5.6)	Project decision. Asset data is being mapped from PowerFactory to PowerOn
5.1.	DERMS will use state estimation techniques	State estimation was considered too slow by the DERMS vendor for the use in the Service Mode (service provision, DER real-time monitoring, control and dispatch). DERMS vendor will implement their own existing 'data-checking' algorithm, subject to the distribution network converging using this method. If in the project trials the solution does not converge using the vendor's algorithm, classic state estimation techniques[15] will be adopted. This will require modifications to the DERMS performance requirements or allocation of additional computational resources to maintain current requirements.	
5.2.	Forecasting function: 24 hours ahead	48 hours ahead	Business requirement from National Grid

[14] Heuristic can be defined as a process relating to exploratory problem-solving techniques that utilise self-educating techniques (such as the evaluation of feedback) to improve performance – Mirriam-Webster definition

[15] https://en.wikipedia.org/wiki/Estimation_theory#Estimators

High-level design (SDRC 9.1) Section	Decision/consideration	Detailed design (SDRC 9.2)	Rationale
5.2.2.	Forecasting engine. Two options were considered: • KASM's[16] Forecaster or • Integrated forecaster from the DERMS vendor	Integrated forecaster developed by DERMS vendor was chosen	• Integrated solution is based on the CIM Data Model (Section 4.5.2) that includes both static and real-time information. • KASM's forecaster includes only two GSPs participating in the project area. • KASM's forecaster predicts load, wind and solar generation, but not synchronous machines or energy storage. • KASM project ends in 2017 and the project would need to engaged KASM's vendor to further develop the software • KASM solution vendor is different to the DERMS vendor

Table 3: Changes from High Level Design - SDRC 9. 1

4.3 DERMS Functionalities Overview

The solution will be implemented as a redundant server-based software product located within the UK Power Networks' IT network and interfacing internally with various UK Power Networks' systems and, externally, with National Grid and DERs. UK Power Networks' systems include the existing Distribution Management System (DMS) PowerOn, developed by General Electric. DERMS will communicate with National Grid via the Platform for Ancillary Services (PAS). DERs located on the distribution network are also external entities with which the solution will interact. (Further information on the systems within Power Potential can be found in Section 4.5.3).

In order to be able to provide reactive and active power services to National Grid and open a route to market for DERs, DERMS will have the following core functionalities:

- A secure mechanism to allow DERs to place bids for service provision ahead of time, view their contracted earnings and service instructions;
- Provision of data relating to availability and cost for reactive and active power services at an assigned 400 kV delivery point (cost curves) to National Grid's PAS;
- A secure mechanism to receive instructions from National Grid's PAS to deliver services;
- A secure mechanism to calculate the optimum DER active power (MW) production dispatch schedule that satisfies a given service request at the lowest cost without violating distribution network constraints;
- A secure mechanism to calculate the optimum DER reactive power (Mvar) services that satisfy a given service request at the lowest cost without violating distribution network constraints;

[16] http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/kent-active-system-management/

- A secure mechanism to send service instructions to the DERs;
- A secure mechanism to visualise the real-time operation of the distribution network;
- Provision of reactive and active power services at the contracted price and volume; and
- A secure mechanism for the generation of aggregated DER performance data based upon actual service delivery at an assigned 400 kV delivery point for settlement purposes between National Grid and UK Power Networks.

More information on the DERMS application components responsible for providing this functionalities can be found in Section 4.4.

4.4 DERMS application architecture

4.4.1 Architecture overview

DERMS application architecture is modular and centred around the database, with modules performing computations in different time horizons and with different frequency. This architecture design allows the software developer to decouple processes and develop functions independently. Moreover, this modular architecture adds flexibility to both the initial development (when each module can be developed in isolation and in parallel with other modules, the only dependency being the input and output data), and subsequent changes or updates (change within one module will not affect – or affect minimally – other modules). This modular architecture is also highly suitable for the staged testing and phased delivery processes.

DERMS application architecture is presented in

Figure 2. Logically (and as a software component) the Forecasting engine is separated from the Future Availability (which includes load flow engine, contingency analysis and optimisation) with the data exchange between them facilitated by the central database.

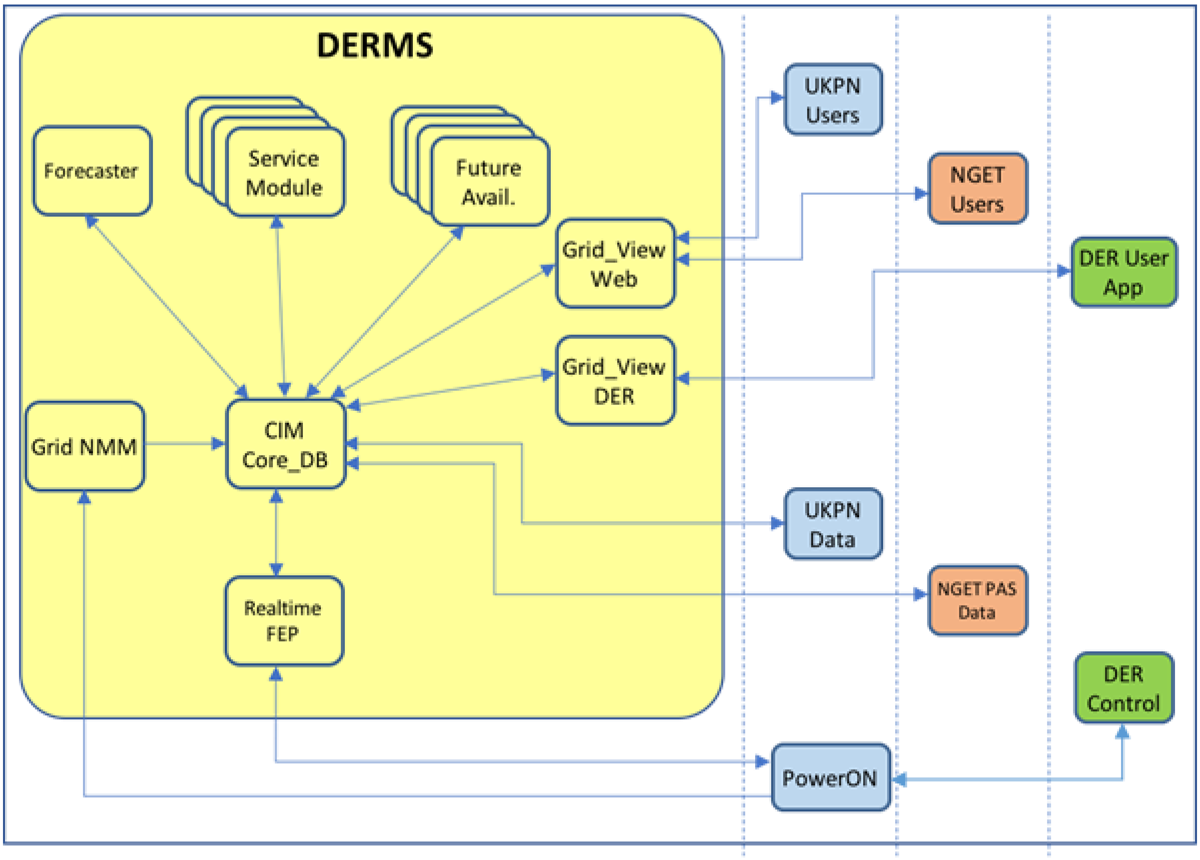


Figure 2: DERMS application architecture

A brief overview of the architecture components is presented in the Sections 4.4.2-4.4.9 below.

4.4.2 CIM Core Database

At the heart of the DERMS is the central database, the CIM Core DB Module. It consists of static configuration, real-time data and historical data elements structured according to the IEC 61968[17] & IEC61970[18] Standards. This database scheme is based on the CIM Model (see Section 4.5.2 for more information) and any necessary relevant extensions. These extensions will be defined where storage of information is required and the nature of that information cannot be modelled by one of the standard CIM data classes.

This database is the key integration point between the internal elements of DERMS and the external entities. All data passing between the differing modules within DERMS and all data passing between DERMS and external entities is mediated through the CIM core database. This database is also the main data store for reporting and any audit trails.

The underlying database is to be realised using MongoDB[19] technology which is a NoSQL[20] database that is well aligned with the JSON[21] data payload to be used within DERMS. It also has mechanisms that will allow for data to be replicated across multiple servers to achieve the redundancy requirements of the project.

[17] https://en.wikipedia.org/wiki/IEC_61968
[18] https://en.wikipedia.org/wiki/IEC_61970
[19] https://en.wikipedia.org/wiki/MongoDB
[20] https://en.wikipedia.org/wiki/NoSQL
[21] https://en.wikipedia.org/wiki/JSON

This replication capability provides redundancy and increases data availability. With multiple copies of data on different database servers, replication provides a level of fault tolerance against the loss of a single database server.

4.4.3 Network Model Manager

This CIM core database is configured and managed by Grid NMM, the Network Model Manager.

The Network Model Manager configures and manages the central CIM Model (more information about CIM model can be found in the Section 4.5.2). It maintains a structured data representation of all aspects of the electrical network and other commercial and non-technical data essential to the operation for the DERMS algorithms. Grid NMM automatically generates configuration files for other DERMS applications including the Realtime FEP (see Section 4.4.4 for more information) mapping data which maps ICCP aliases to points in the CIM database.

The Grid NMM provides the following high-level functions within the DERMS architecture:

- Automatically imports the CIM data (containing the network model, connectivity information, asset data, and SCADA point mapping data) from PowerOn;
- Validates the imported CIM data;
- Merges the imported CIM data into the DERMS CIM database;
- Aggregates network connectivity nodes to reduce network complexity; and
- Exports the CIM data into formats for use by other DERMS components (internal DERMS formats).

DERMS will automatically detect and retrieve any new CIM export file and perform pre-processing on the file.

CIM Import Validation

Once the data is imported from PowerOn it is validated using the built-in validation functions. These include:

- Checking the data is a valid XML;
- Checking the data conforms to the serialisation format rules (e.g. IEC 61970-552 CIM RDF XML) including validating XML namespaces;
- Checking the data against the meta-model class structure and that classes, attributes and references are valid (e.g. ensuring any classes or attributes exist in the declared version of CIM or any customer-defined extensions); and
- Executing detailed validation rules defined in the Object Constraint Language (OCL) including standard rule sets based on IEC and ENTSO-E standards and custom rules defined specifically for DERMS.

The topological processor also checks for unexpected islanding in the network.

Data Merge

Grid NMM will merge the datasets from the PowerOn CIM import into the DERMS Core CIM Database. It will merge the imported data for each 400 kV delivery point with the existing CIM data, including DERMS-specific configuration data, forecast data, service data, the real-time network data and historical data.

Network Topology Processing

Grid NMM has the ability to perform topological processing of the imported electrical network model to identify topological islands and perform network simplification. This simplification can take the form of bus-branch (CIM topological node) generation starting from a detailed node-breaker (CIM connectivity node) within the model. This is commonly used for generating network models for power flow analysis.

The topological processing can also be used to identify network parts downstream of a node (e.g. identifying the extent of a feeder) and then optionally collapse these network parts into single nodes with equivalent load and generation calculated from the downstream network part.

CIM Application Configuration

As well as configuring the main CIM Core Database, Grid NMM also generates configuration files for each of the DERMS applications. When the PowerOn model changes then Grid NMM:

- Generates a new network segment model and configuration file for each 400 kV delivery point Service Mode application;
- Generates a new network segment model and configuration file for each 400 kV delivery point Future Availability Mode application;
- Generates the configuration file for the Realtime FEP application to define what data points to retrieve in real-time over ICCP; and
- Generates the configuration file for the Forecaster application to define the location and capacity of each participating DER.

Automatic import of the PowerOn CIM data structures ensures that the DERMS system remains synchronised with the DMS at all times. This significantly reduces the engineering, validation and testing efforts required to keep the advanced network applications and data flows synchronised with the actual network at all times.

Although this process will be automated, the initial phase of the project may require manual matching of assets and IDs from the different datasets due to CIM export functionality being gradually added to PowerOn over 2018. During the development phase of the project the first 400 kV delivery point will be manually configured to facilitate software development and testing.

4.4.4 Realtime FEP

The Realtime FEP (Front-End Processor) module provides the real-time SCADA control and communication interfaces to external systems, i.e. UK Power Networks' DMS (PowerOn). Realtime FEP manages the ICCP interface with PowerOn which, in turn, interfaces to the remote RTUs and DER equipment via other SCADA protocols. The module handles all real-time SCADA data and populates the central database (CIM Core) with this data to be used by other DERMS application modules. The module also issues the set-points and commands generated by DERMS for DERs (via PowerOn and the ICCP interface).

The Realtime FEP module has two interfaces. On one side it will has an ICCP client and server interface facing the PowerOn DMS and on the other side it has a restful ODATA[22] interface in JSON[23] format facing the DERMS CIM Core database.

The Realtime FEP module will reside on a virtual machine within the DERMS environment which runs the Windows® operating system.

[22] https://en.wikipedia.org/wiki/Open_Data_Protocol

[23] https://en.wikipedia.org/wiki/JSON

4.4.5 Forecaster Module

The Forecaster Module takes data from the CIM Core Database including the current network configuration, historical data and other data such as weather forecast information, to generate a forecast for all generation (wind, solar, synchronous generators) and demand in the trial area. The forecast is generated periodically (every 30 minutes) for the forecast interval and stored in the CIM Core Database.

4.4.6 Future Availability Module

The Future Availability module takes inputs from the Forecaster module (via the CIM Core Database) and other commercial and network data to calculate, in an optimal way, the active and reactive power aggregated availability of DERs to provide services at the 400 kV delivery point. This calculation is based on the integrated load flow engine (implemented in IPSA[24]) and the scheduling algorithm (heuristic optimisation). The load flow engine takes as an input the forecasted generation and demand, the network model with 'future' switch statuses (obtained from the planned outages) and produces 'future' load flow. This load flow is then used as a constraint in the optimisation routine (scheduling algorithm) in order to ensure that selected generation levels are within distribution network thermal and voltage constraints.

The scheduling algorithm uses the DER declared availability to calculate availability (measured in Mvar or MW) of each service at the 400 kV delivery point level whilst minimising service costs (or maximising speed of response for MW service). This algorithm includes distribution network constraints, contingency analysis and outages (present and future in the distribution network). It removes DER MW or Mvar volume that is unavailable due to the distribution constraints (or 'set aside' to manage those constraints, e.g. via ANM scheme), performs contingency analysis based on a pre-defined set of possible network events (defined by UK Power Networks) to ensure that the offered active and reactive power services will be provided within a secure distribution network.

The algorithm generates service availability as cost curves (and, additionally, response curves for the active power service) for each 400 kV delivery point for the 48 hours ahead and presents them to National Grid via the PAS. The cost curves present the service based on both availability and utilisation prices and are updated every 30 minutes.

4.4.7 Service Module

The Service Module takes real-time inputs from the SCADA network (retrieved by the Realtime FEP module from PowerOn and stored in the CIM Core Database) and other network data (For detail see section 4.5.3 and Figure 3) to calculate the optimal dispatch arrangement for the generators procured for service which respects distribution network constraints.

The Service module is based on an integrated load flow engine and the scheduling (optimisation) algorithm. Based on the cost curves produced by the Future Availability module, National Grid (via PAS) will instruct DERMS with either an MW volume reduction/increase or a voltage target set-point to be delivered at the 400 kV delivery points.

The Service module will calculate the optimum DER production dispatch that satisfies the service request at the lowest cost without breaching any distribution network constraints or breaching DNO system security and quality of supply standards. DERMS will issue set-points to DERs and other control equipment to achieve the service levels required by National Grid. These instructions are transmitted to the relevant equipment via the Realtime FEP module and PowerOn.

[24] https://www.ipsa-power.com

4.4.8 Grid View Web

Grid View Web is a visualisation platform for UK Power Networks that handles the integration between UK Power Networks' users and the CIM Core Database. It provides a user management system for data visualisation and user data entry.

Grid View Web accesses the CIM Core Database to allow any combination of real-time data, historical data, asset data, geographical data, availability data and commercial data to be represented and accessed remotely by a variety of users.

The proposed visualisation options for this project will be built upon this existing platform, ensuring that the full geographical model, along with the user specific real-time overlays are provided. Viewing privileges can be assigned based on different roles/users. This means that the same visualisation portal can be used by various users across UK Power Networks offering different overlays and views.

4.4.9 Grid View DER

Grid View DER is a mobile visualisation platform that handles the integration between remote user interfaces and the CIM Core Database. It provides a user management system for data visualisation and user data entry.

Grid View DER is a portal for DERs that provides:

- DER operators the ability to enter and update availability and utilisation pricing (bids) which feed into the Future Availability and Service modules' functions (via CIM Core database); and
- Displays for DERs to view their planned generation and forecasted earnings (after the auction).

4.5 Data in the project

4.5.1 Importance of Data to the Project

The project is centred around DERMS – a data-intensive application, which, among other functions, produces forecasts, performs contingency analysis, runs optimisation routines and employs automation of processes (including distribution network monitoring, DER dispatch and control). Therefore, DERMS heavily relies on data to perform these functions in adherence to the business and technical requirements and, as a consequence, to facilitate the project in delivering its value.

The benefits to DERMS (and, hence, the project) from the detailed datasets definition and data quality should not be underestimated: by accurately forecasting generation and demand, DERMS will be able to provide better estimates of the service available in the distribution network, thus maximising value of the service to the transmission network and increasing revenue streams for DERs.

The following sections cover a number of areas in the data domain that needed to be investigated and refined so that necessary data support for DERMS can be provided by the project. The section is structured as follows:

- Section 4.5.2 introduces CIM data model adopted in DERMS;
- Section 4.5.3 maps data sources for DERMS within the project;
- Section 4.5.4 presents data exchange flows between DERMS and data sources in the project in two operational time horizons of the solution (Future Availability and Service Mode);
- Section 4.5.5 references the Data Dictionary document. Data Dictionary contains all datasets (with details), identified in the Section 4.5.4 as critical to the DERMS operation; and
- Finally, Section 4.5.6 highlights the importance of the data quality for the project and puts it into a wider context of the changing nature of the electricity networks. It also presents the measures to improve data quality undertaken as part of the project.

4.5.2 Data model

All data within DERMS will be stored in the CIM format. CIM stands for the Common Information Model and is an open standard developed by the electricity power industry that has been officially adopted by the International Electrotechnical Commission (IEC). It aims to allow application software to exchange information about an electrical network.

The CIM is currently maintained as a Unified Modelling Language (UML) model. It defines a common vocabulary for aspects of the electric power industry. The CIM models the network itself using the 'wires' package. This package describes the basic components used to transfer electricity. Measurements of power are modelled by another class. These measurements support the management of power flow at the transmission level, and, by extension, on the distribution network.

The CIM is also used to derive messages for the wholesale energy market with the framework for energy market communications, IEC 62325[25].

The standard that defines the core packages of the CIM is IEC 61970-301[26], with a focus on the needs of electricity transmission, where related applications include energy management system, SCADA, planning and optimisation. The IEC 61970-501 and 61970-452 standards define an XML format for network model exchanges. The IEC 61968[27] series of standards extend the CIM to meet the needs of electrical distribution, where related applications include distribution management system, outage management system, planning, metering, work management, geographic information system, asset management, customer information systems and enterprise resource planning.

CIM export functionality is currently being developed by General Electric for the UK Power Networks Distribution Management System (DMS) (PowerOn), with functionality being added in stages during 2018. The solution will be tested and available by early 2019 (before the project's live trials with DERs commence).

4.5.3 Data sources

After DERMS functionality was established and the required datasets were defined, the next step was to map the sources of this data in the project.

Figure 3 shows the project's data sources and their high-level interaction with DERMS and each other. Data sources are grouped into three broad categories: UK Power Networks data sources, National Grid data sources and other data sources.

[25] https://en.wikipedia.org/wiki/IEC_62325

[26] https://en.wikipedia.org/wiki/IEC_61970

[27] https://en.wikipedia.org/wiki/IEC_61968

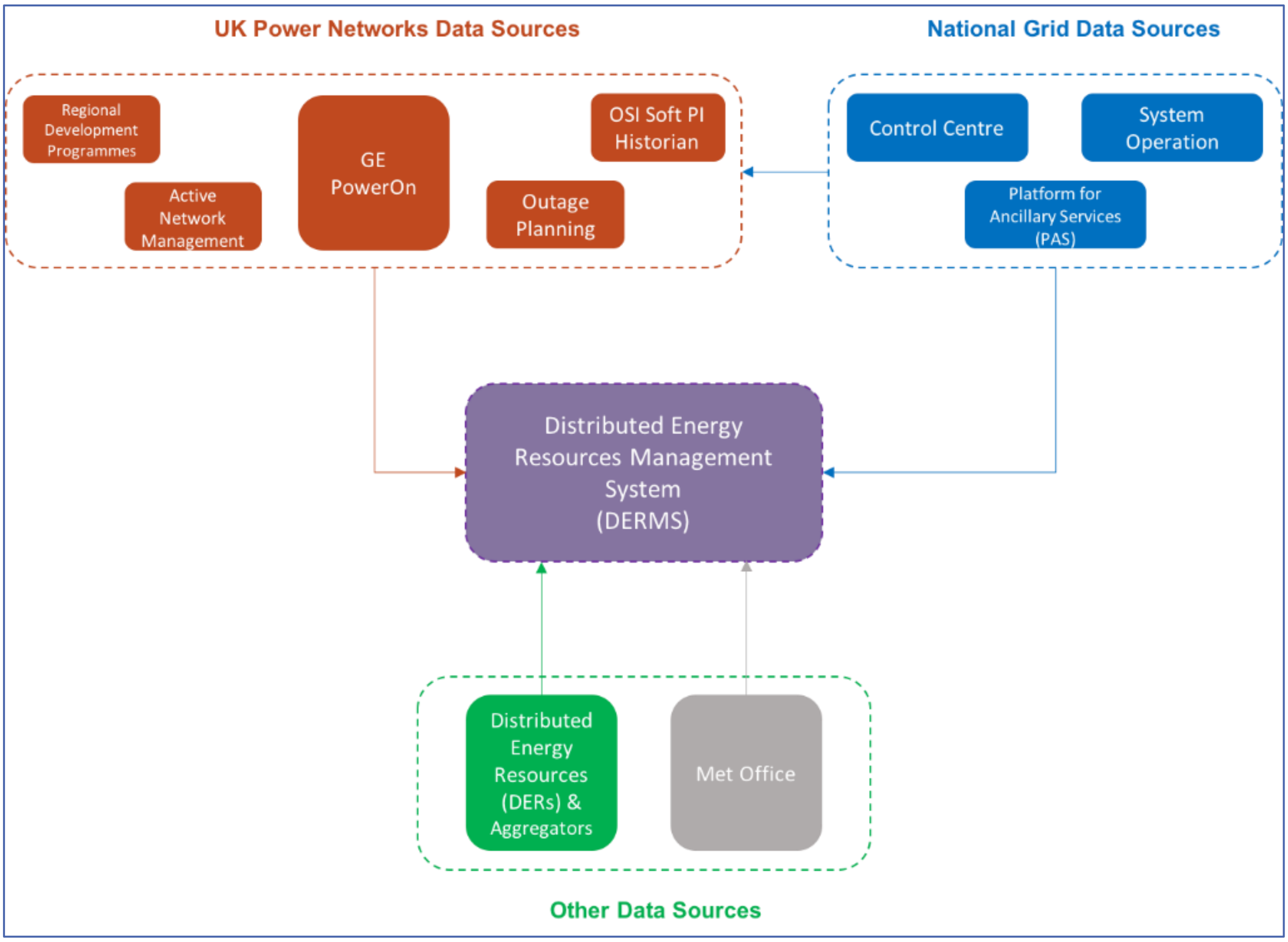


Figure 3: Data sources in Power Potential

The following sections provide a brief description of the data sources and their role in the project.

UK Power Networks data sources

GE PowerOn

GE PowerOn Fusion is UK Power Networks' DMS, which is used in the control room to manage the network in real-time. The DMS represents the 'live' running configuration of the network. The DMS receives SCADA data from Remote Terminal Units (RTUs) in the field and presents this data on a network diagram in the application. The DMS provides alerts based on the user-defined limits of equipment and also allows remote switching capability on the majority of the EHV/HV networks.

PowerOn Fusion is the source of the real-time network configuration and SCADA data (measurements), which will be used by DERMS both in the Future Availability (combined with planned outages) and in the Service Mode operational horizons. The real-time network configuration will be exported from PowerOn at the configurable time interval (it might change to 'on network changes', depending on what will be the most time and computationally efficient option for the solution).

PowerOn also contains the real-time network data from the distribution network system, which includes voltages (reported against busbars), currents (reported against individual switches or circuit breakers), switch states and transformer tap positions.

In SDRC 9.1 (section 4.1.2.1)[28] it was suggested that some asset electrical parameters (e.g. cable ratings and impedances) would come from PowerFactory. The project has since decided that PowerOn

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

will be the source of the network model, real-time measurements and all asset electrical parameters. Changes to PowerOn is required to make it the master source for all real time data. Current activities include mapping of asset data from PowerFactory to PowerOn. More information can be found in the Section 4.5.6.

PowerOn also contains the South Eastern section of National Grid's transmission network, including SCADA data (real-time measurements).

OSIsoft PI Historian

OSIsoft PI Historian is the UK Power Networks' SCADA historian into which all available real-time data from the DMS is archived. Each network analogue measurement has a PI tag associated to it, which provides the ID for retrieving the data from the PI database. PI uses a swinging door algorithm (a swinging door algorithm allows servers storing data to compress it by only storing what is determined to be meaningful data, allowing to improve disk space and reducing network traffic) to store data and so it only stores a timestamp of change where the change is greater than or less than a given percentage of the current value. It then interpolates the missing values.

In the project the PI database is used to extract historical load and generation data that is used to train the load and generation forecasting algorithms.

Regional Development Programmes (RDP)

The Regional Development Programmes (RDPs) were set up to provide detailed analysis of areas of the network which have large amounts of DERs and known transmission/distribution network issues in accommodating those DERs.

The South Eastern distribution network has seen a significant increase in generation connected over the past five years. This has resulted in distribution constraints emerging under certain load and generation patterns.

Protection schemes are currently in place to ensure that overloads are prevented. However, these key pinch-points could be subject to overloads that would require managing should more DER connect in the area. Therefore, as some of the DERs connected in the area will be participating in the project (and hence dispatched/released from service by DERMS), DERMS would need to receive information about the existing constraints from RDP and ANM.

Active Network Management (ANM)

An Active Network Management (ANM) system will be designed for the South Coast to manage distribution network constraints. The ANM will be managing distribution constraints and constantly communicating with DERMS by exchanging signals to avoid conflicts of services. This will result in DERMS accurately providing the visibility and availability of DER services to National Grid. In addition, DERMS will be avoiding conflicts of services by informing National Grid of the headroom and footroom constraints. Hence the direct dispatch of other DER services sitting behind ANM schemes will not be nullified by ANM operation. Figure 4 shows the high-level interaction between ANM and DERMS.

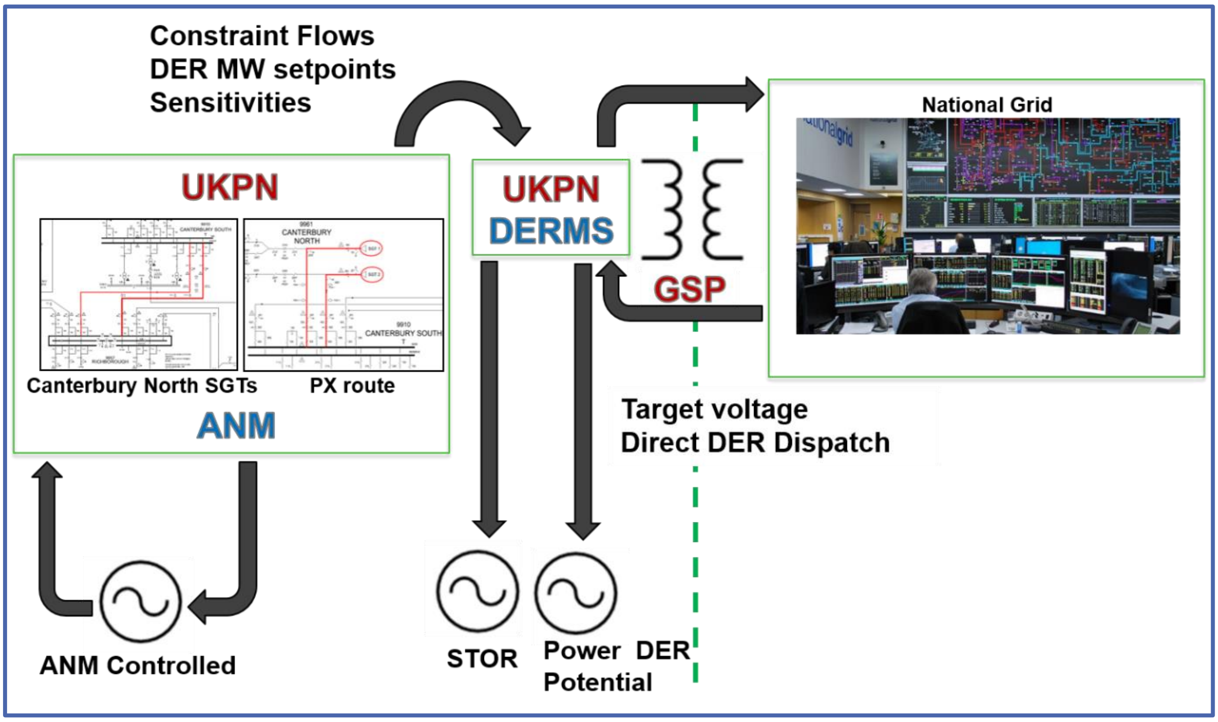


Figure 4: High-level interaction between ANM and DERMS.

More information on RDP, ANM and conflicts of services can be found in SDRC 9.1 (Sections 9.1 and 9.2)[29].

Outage Planning

An Automated Outage Management System (AOMS) is currently being developed by UK Power Networks outside of this project. However, as it is expected to go live at the end of 2018, an interim solution will be implemented for DERMS. Planned outages will be fed into DERMS via the formatted CSV file. DERMS will then associate this list with the network model imported from PowerOn for the use in the Future Availability operational horizon.

National Grid data sources

National Grid Real-Time Data (NG Control Centre)

As the Great Britain transmission system operator, National Grid is responsible for managing the transmission network in the project area. Real-time SCADA data is transmitted over an ICCP link that connects the UK Power Networks and National Grid control rooms. DERMS will collect transmission network SCADA data via the PowerOn CIM extract.

National Grid Forecast Data

The DERMS forecasting engine will receive National Grid's wind generation forecast data. This forecast data includes 0-4 day-ahead wind generation forecasts at an individual site level, on an hourly basis, for sites larger than 100kW. This data will be used as an input to the DERMS Forecasting engine.

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

Platform for Ancillary Services (PAS)

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

DERMS will exchange information with PAS for each 400 kV GSP delivery point during the following timescales:

- **Pre-auction:** DERMS will send signals to PAS on service availability and costs (active power and reactive power services) for each 30 min period going forward 48 hours;
- **Auction and post-auction:** after the auction when the data in DERMS is frozen, PAS will enable the control room in National Grid to confirm the service requirements and procured services;
- **Real time:** during service delivery, PAS will send instructions to DERMS and receipt of service delivery and real time signals from DERMS; and
- **Settlements:** after service delivery, data from PAS will input to the relevant settlement process.

Other data sources

The Met Office

The Met Office is a national weather service provider in the UK. For the project, the Met Office is the source of weather data including observational and forecast information. Weather forecast data will be periodically provided to UK Power Networks by the Met Office via Excel files. The service will include a number of weather station sites which cover the geographic area of the Power Potential trials. The data will be used to train the forecasting algorithms and as an input to the live forecasting engine.

This enables DERMS to predict the generation for a given DER.

Distributed Energy Resources (DERs) and Aggregators

DERMS is designed to support a variety of DER technologies, non-synchronous such as wind, solar, storage and also synchronous machines (e.g. CHP). Each DER is represented in DERMS as a CIM object with a collection of parameters. A detailed list of these parameters was developed in the detailed design stage and can be grouped into three broad categories:

- Technical characteristics describing a DER capability to provide one or both services (e.g. P-Q capability curves);
- Commercial (bids), indicating the readiness to provide the service and the expected availability and utilisation payments; and
- Other technical parameters that will allow DERs to be controlled and dispatched by DERMS.

As long as a DER or an aggregator is able to provide parameters from all these three categories, it can be modelled in DERMS (thus becoming a data source). Some of these characteristics are common for all DERs (e.g. capability curve) and some are technology-specific (e.g. irradiation for solar, cut-off speed for wind or voltage control mode specific to non-synchronous or synchronous plants).

4.5.4 Data exchange in Power Potential

DERMS operates in two time horizons: Future Availability (forecasting and maximisation of the aggregated service at the 400 kV delivery points level) and Service Mode (service provision, DER dispatch, network monitoring and post-response settlement), with both parts having different datasets exchanged.

Future Availability data exchange

In the Future Availability operational horizon (Forecaster (Section 4.4.5) and Future Availability (Section 4.4.6) DERMS architecture components) the datasets as shown in Figure 5 are exchanged between the following components:

- **DERMS Forecaster** receives weather forecast data from Met Office, historical demand and generation data from the UK Power Networks PI Historian and wind forecasts from National Grid. These are used to generate the demand and generation forecasts (48 hours ahead on a rolling basis).
- **DERMS Load flow engine** receives demand and generation forecasts, network model in CIM format from PowerOn and planned outages from the UK Power Networks outage planning tool to create an expected 'future' load flow.
- **DERMS Contingency analysis** uses the 'future' load flow and the list of credible contingencies to run contingency analysis.
- **DERMS Optimisation routine** runs the DER scheduling algorithm while using load flow, contingencies and ANM/RDP data as constraints to ensure generation chosen for the service provision will be within distribution thermal and voltage constraints.

After optimisation is complete, DERMS outputs **cost curves** for both active and reactive power services to National Grid via PAS.

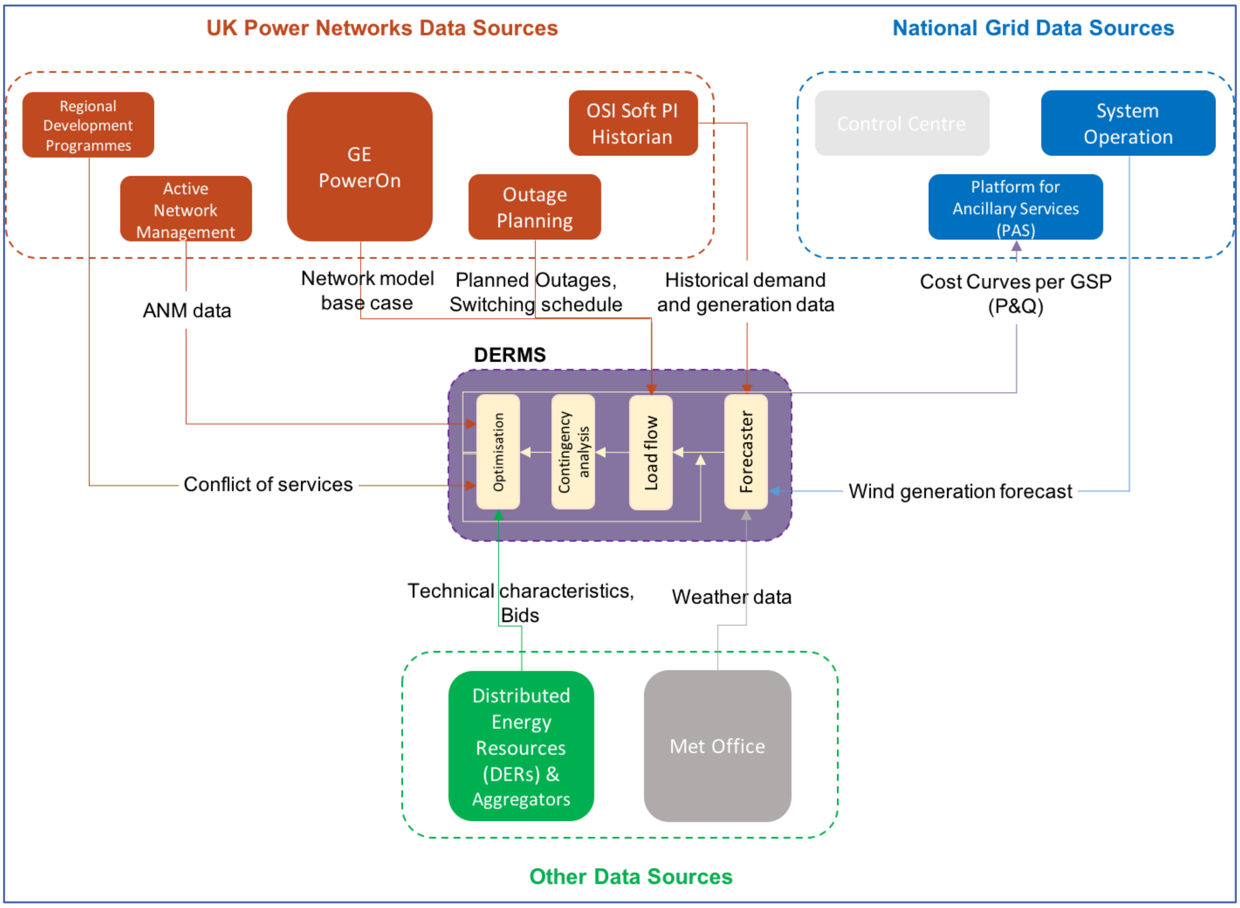


Figure 5: Data exchange in the Future Availability operational horizon (Forecasting and Future Availability modules)

Logically all data exchange between external sources and DERMS and amongst DERMS components will be mediated by the DERMS central database (Section 4.4.2) called CIM Core DB.

Service Mode data exchange

In the Service Mode (Service Module (Section 4.4.7) DERMS logical architecture component) operational horizon the datasets are exchanged between the following components:

- After the auction, if National Grid decides to procure one or more services from DERMS, it sends an instruction via its PAS application. Instruction to DERMS would contain voltage set-point at the 400 kV delivery point (grid supply point) or MW export set-point (depending on the service procured).
- DERMS will use its heuristic **optimisation module** to calculate set-points (voltage and/or MW) for DERs.
- DERMS will then issue instructions to DERs via **PowerOn**.
- In the real-time (during service delivery) DERMS will monitor the load flows in the distribution network and DER performance by receiving real-time network and DER performance measurements, as well as real-time ANM and conflict of services signals (all through **PowerOn**). DERMS will be continuously recalculating load flows in the distribution network, as well as the amount of service delivered at the 400 kV delivery point(s). It will adjust DER set-points if necessary, to ensure the delivery of service at the 400 kV delivery point(s) is fulfilled and the safety and security of the distribution network is maintained.

- After the service delivery is over, DERMS will produce settlement data at both 400 kV delivery point (aggregated) and for each DER that participated in the service provision (disaggregated).

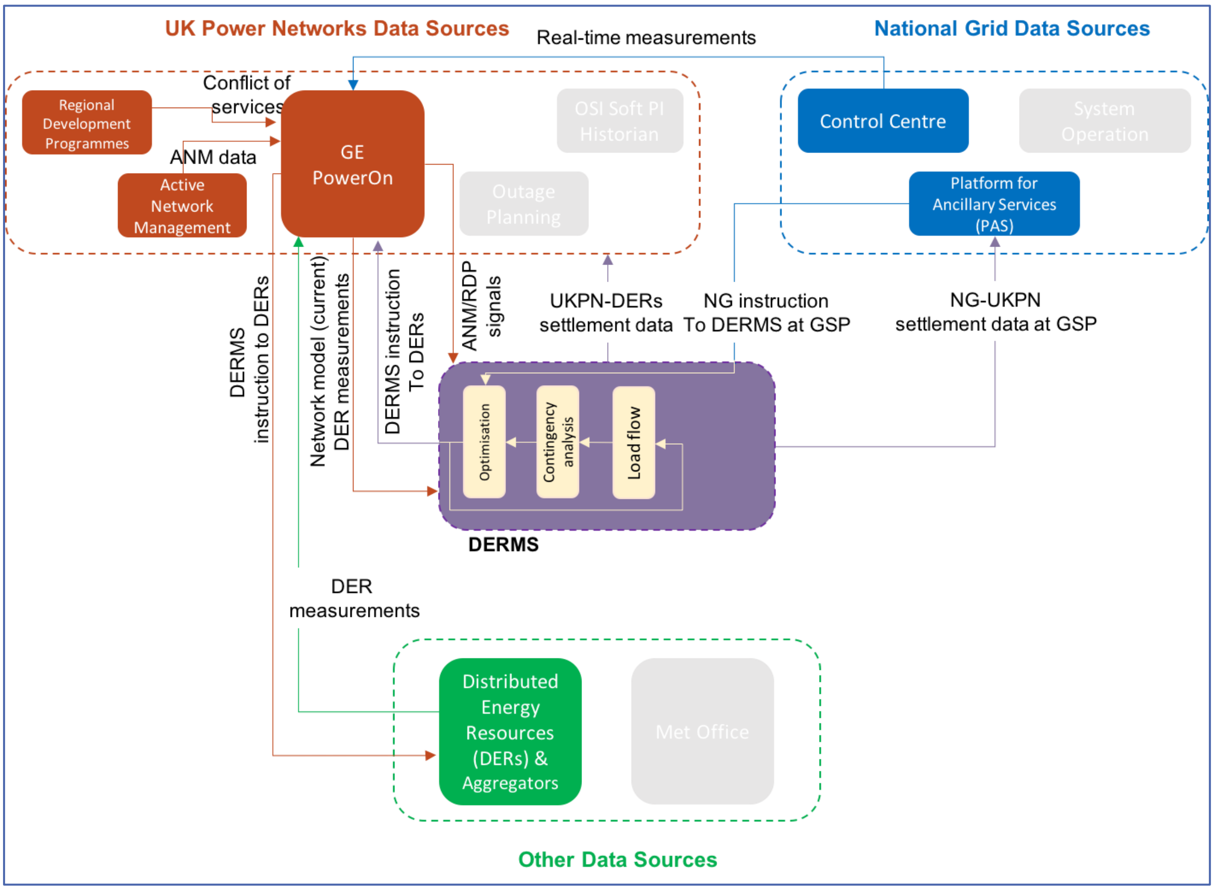


Figure 6: Data exchange in the 'Real time' (Service Mode)

Logically all data exchange between external sources and DERMS, and among DERMS components will be mediated by the DERMS central database (Section 4.4.2) called CIM Core DB.

4.5.5 Data dictionary

Data dictionary[30] is one of the core documents in the DERMS design and development process. It contains all datasets outlined in the Section 4.5.4, with the format of the data, the data source and data destination for every dataset item.

4.5.6 Data Quality

Accuracy of transmission and distribution networks data is vital for the proposed solution. In the past where and when data quality was compromised, values of various parameters such as currents, voltages, voltage angles and active/reactive power were used in state estimation techniques. However, state estimators involve relatively slow computations and in the case where, like in DERMS, a lot of data points need to be known, need to be accurate and to be availably quickly (e.g. in the real-time network monitoring and control) for the software to perform its functions correctly, state estimator might not be the most suitable solution to the data quality problem.

It might be argued that state estimator (even with underlying costs for the sufficient computational resources to run it within acceptable time limits) would still be less expensive than to roll-out

[30] Data Dictionary, Confidential, A. Ahmadi

transducers (sensors)[31] across the network. However, the data quality requirement is much larger than the needs of the project.

With increasing automation and control in the electrical networks and the adoption of software solutions to perform these actions, data quality becomes critical for both a DNO's business as usual operation and for its transition to a DSO. Therefore, a number of actions are currently being undertaken in parallel within the project to address the existing data quality issues, minimise their negative impact on the DERMS solution and the project (with a wider benefit to UK Power Networks):

- The DERMS vendor has proposed a data-checking algorithm, which is faster than classic state estimation. This algorithm is currently under investigation for load flow convergence. If load flow on the project's area of the UK Power Networks network converges consistently with the vendor's algorithm, then it will be considered for the solution. Otherwise, the development of the state estimator (with its associated impact on the DERMS computational speed or infrastructure costs to maintain computations within required time limits) will need to be considered.
- UK Power Networks is undertaking the study on the optimal placement of sensors with subsequent installation of these sensors (transducers).
- In the project, PowerOn will be the master for all electrical network data. However, more detailed asset data, such as transformer and cable ratings and cable impedances, are stored in DigSILENT PowerFactory. Therefore, UK Power Networks is undertaking an ongoing work on aligning PowerOn with PowerFactory to reflect accurate asset parameters.

4.5.7 Data Storage

DERMS database is currently designed to store data for 30 days, after which permanent storage within UK Power Networks will be used.

4.6 Communications and Interfaces in the Project

The following section sets out the Communications Architecture of the project and the interfaces between various systems that will interact with each other and DERMS in order to enable its operation. Definition of communication links, protocols and interfaces at the design stage is critical to the successful integration of DERMS with these systems.

- Section 4.6.1 provides summary description of the adopted communication protocols.
- Section 4.6.2 describes how interfaces will be implemented.
- Section 4.6.3 gives an overview of the project's communications architecture in the Future Availability (Day-ahead) and Service Mode (Real-time) DERMS operational horizons, with the list of interfaces presented in the Figure **7** and Figure 8 respectively.

4.6.1 Communication protocols utilised by the project

Candidate communication protocols to be used in the project were discussed in the Section 4.1.2.3 of SDRC 9.1[32]. All three types of protocols described in the SDRC 9.1 will be employed: ICCP[33], Web-services[34] and DNP3[35]. The brief description and benefits of these protocols to the project are summarised below:

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31 https://en.wikipedia.org/wiki/Transducer

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

33 https://en.wikipedia.org/wiki/IEC_60870-6#Inter-Control_Center_Communications_Protocol

34 https://en.wikipedia.org/wiki/Web_service

35 https://en.wikipedia.org/wiki/DNP3

- **ICCP (Inter-Control Centre Communications Protocol)**[36] is a protocol designed for control system to control system integration. ICCP has already been implemented between UK Power Networks and National Grid for the KASM project[37] and enables sharing of the real-time data between the two parties. It is configured by using a subscriptions table and allows for multiple subscribers to the same data points. It is an open standard protocol and thus was selected for the DERMS-PowerOn integration.
- **Web Services**[38] allow the systems to send outbound messages as state changes occur. These messages can be in the JSON format, which is supported by DERMS, thus simplifying integration. The communication link between National Grid's PAS and UK Power Networks' DMS (PowerOn) will be implemented as a Web Services, as National Grid uses this type of link with other service providers (e.g. STOR). This will be a new Web link (and interface) between National Grid and UK Power Networks. PowerOn currently does not have Web Services interface functionality and various implementation options are being investigated by UK Power Networks.
- **DNP3**[39] is a widely-used SCADA protocol and allows for synchronous messages to be communicated between devices/systems. DNP3 is an open standard protocol and is adopted by UK Power Networks for the PowerOn-RTU data exchange.

4.6.2 System interfaces in Power Potential

Communication interface topology options were discussed in the Section 4.1.2.6 of SDRC 9.1[40]. At the Detailed Design stage the use of hybrid topology was confirmed, with both point-to-point and bus interfaces. The following section provides brief overview of the adopted approach to the technical implementation of the DERMS interfaces with the data sources identified in the Section 4.5.3.

An interface is a shared boundary across which two or more separate components of a computer system exchange information. A key principle of design is to prohibit access to all project systems by default, allowing access only through well-defined entry points, i.e. interfaces.

DERMS will adopt the Application Programming Interface (API)[41] approach.

ODATA

OData[42] is the protocol on which the standard DERMS API is based. Open Data Protocol (OData) is an open protocol which allows the creation and consumption of queryable and interoperable RESTful APIs in a simple and standard way. The protocol enables the creation and consumption of REST APIs, which allow web clients to publish and edit resources, identified using URLs and defined in a data model, using simple HTTP messages.

OData uses URLs to identify resources. For every OData service, the following fixed resources can be found:

- The service document lists entity sets, functions, and singletons that can be retrieved. Clients can use the service document to navigate the model in a hypermedia-driven fashion;

36 https://en.wikipedia.org/wiki/Web_service
37 http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/kent-active-system-management/
38 https://en.wikipedia.org/wiki/Web_service
39 https://en.wikipedia.org/wiki/DNP3
40 https://www.nationalgrid.com/uk/investment-and-innovation/innovation/system-operator-innovation/power-potential
41 https://en.wikipedia.org/wiki/Application_programming_interface
42 https://en.wikipedia.org/wiki/Open_Data_Protocol

- The metadata document describes the types, sets, functions and actions understood by the OData service;
- The data structures exposed by the metadata are based on the CIM model and any relevant extensions; and
- DERMS clients can use the metadata document to understand how to query and interact with entities in the service.

JSON

JSON (JavaScript Object Notation)[43] is a lightweight data-interchange format used to transfer responses to ODATA query/requests. As well as being easy for users to read and write, it is also easy for machines to parse and generate.

JSON is based on a subset of the JavaScript Programming Language, Standard ECMA-262 3rd Edition – December 1999. JSON is a text format that is completely language-independent but uses conventions that are familiar to programmers of the C-family of languages, including C, C++, C#, Java, JavaScript, Perl, Python and many others.

These properties make JSON an ideal data-interchange language for DERMS.

4.6.3 Overview of the Communications Architecture and Interfaces

Most of the systems participating in the data and signals exchange (hence, utilising these communication links) were presented in Section 4.5.3. The diagrams in the Figure 7 and Figure 8 introduce two new elements: Remote Terminal Units (RTUs) and Enterprise Service Bus (ESB).

A RTU is a device wired into the substation plant and feeds back analogues (for example volts, amps, MW) and digitals (for example switch states, alarms) to PowerOn.

An ESB is a messaging platform that supports data messaging between applications. The main advantage of using an ESB is the 're-usability' of data or services that pass through it. If some project data or requests (from PAS, DERMS, PowerOn or DERs/aggregators) may be useful elsewhere within UK Power Networks, publishing them on ESB in an open/standardised format means that other projects can subscribe to them later. This will avoid going to the source system (as would be the case with the point-to-point interface), saving time, money and reducing impact on the source systems.

Figure 7 and Figure 8 present communication links utilised within Power Potential in the Future Availability and Service Mode DERMS operational horizons respectively, as communications architecture and interfaces are based on the Data Exchange Flows presented in the Section 4.5.4

[43] https://en.wikipedia.org/wiki/JSON

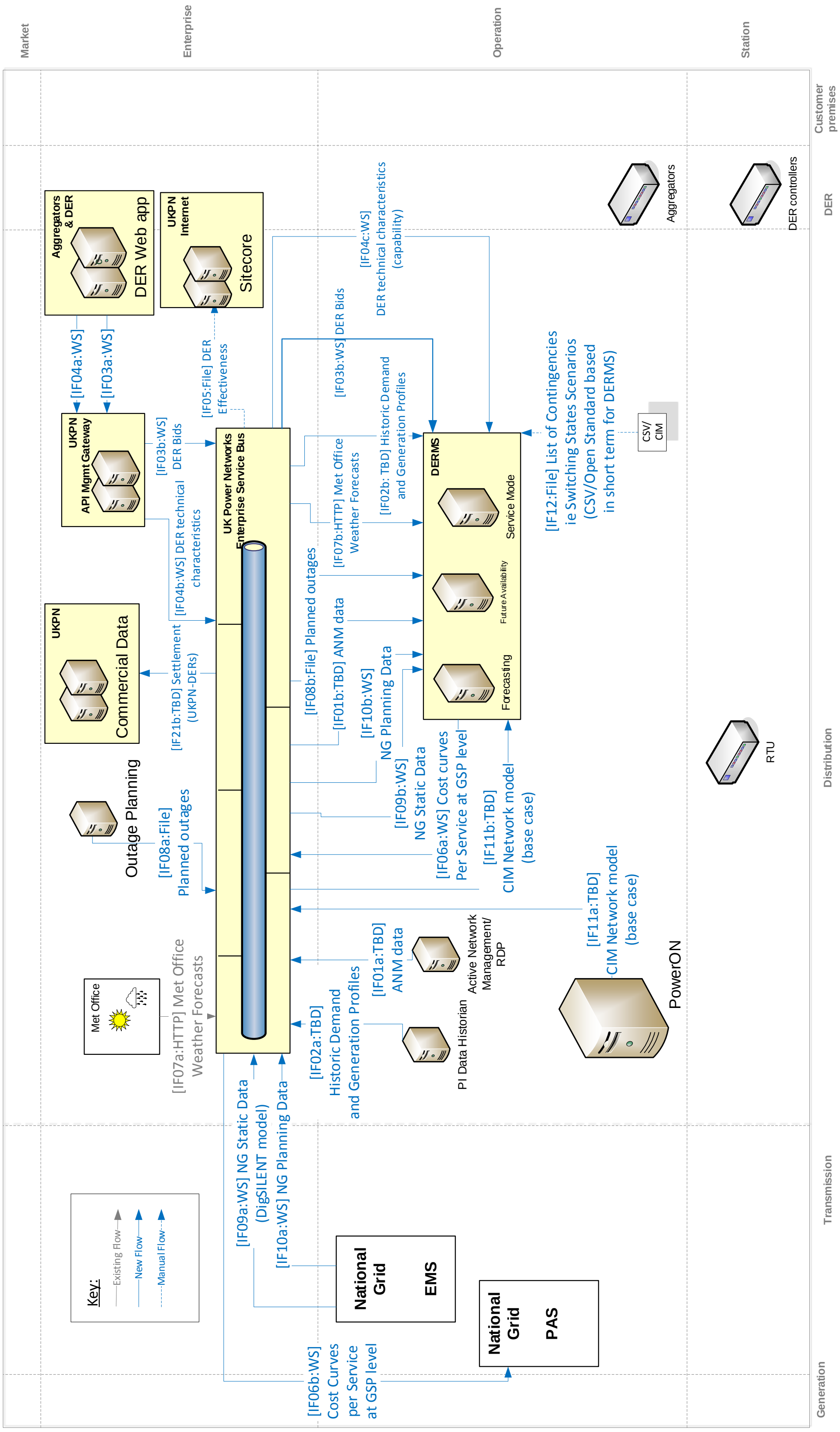


Figure 7: Forecasting and Future Availability Communications Architecture and Interfaces in Power Potential

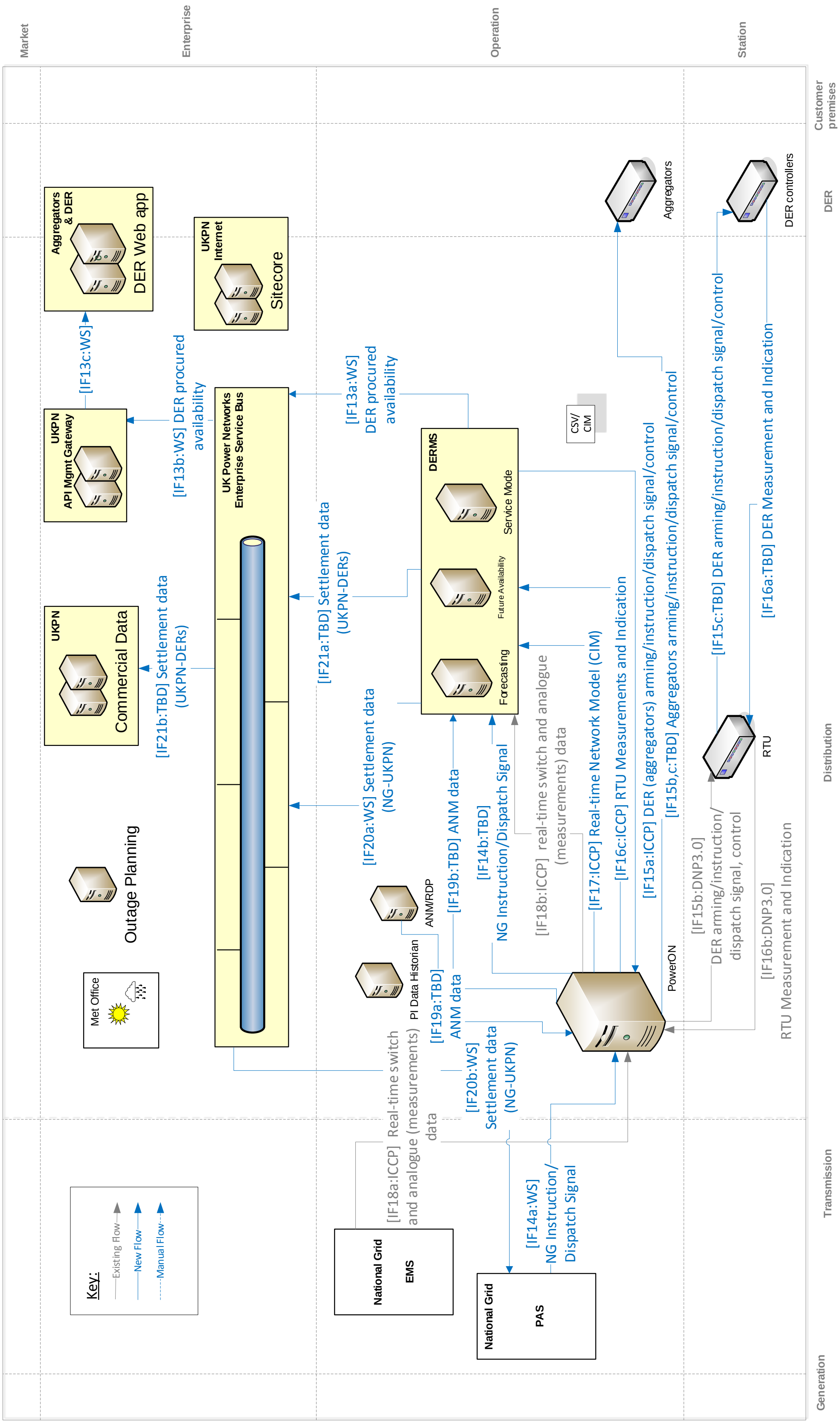


Figure 8: Service Mode Communications Architecture and Interfaces in Power Potential.

Interfaces between various project components in the Future Availability and Service Mode are summarised in the Table 4 and Table 5 respectively:

I/F ID	Interface Name	Protocol	Source System Component	Target System Component	Data	Interface Purpose
IF01	**Historic Curtailment Profiles**	To be decided	UK Power Networks' ANM (via ESB)	DERMS	Historic curtailment profiles and other services procured	Data will be used by the DERMS to calculate dispatch availability.
IF02	**Historic Demand and Generation Profile**	To be decided	PI Data Historian (via ESB)	DERMS	Historic demand and generation	Data will be used by the DERMS to train forecaster. Forecasted generation and demand then will be used to create load flow for the Future Availability calculations
IF03	**Bid**	Web-services	DER	DERMS (via ESB and UK Power Networks' API management gateway)	Generation availability, price	Data will be used by the DERMS to calculate dispatch availability.
IF04	**Capability (DER technical characteristics)**	Web-services	DER	DERMS (via ESB and UK Power Networks' API management gateway)	Generation capability	Data will be used by the DERMS to calculate dispatch availability.
IF05	**DER Availability Effectiveness (sensitivity)**	File	DERMS (via ESB)	DER	Geographic network map indicating effectiveness areas (high/medium/low), i.e. the impact of a given generator's production at the change in voltage at GSP	Data will be used by the DERs to assess their effectiveness.
IF06	**Availability Per Service Cost Curve**	Web-services	DERMS (via ESB)	National Grid's PAS	Price and aggregated availability and utilisation data	Aggregated availability per 400 kV delivery point per service to enable National Grid to make decisions upon which services are the most cost-effective to procure at a given time.
IF07	**Weather service**	HTTP-based Web Service	Met Office (via ESB)	DERMS	Weather data	The DERMS will use the weather data for forecasting generation availability and demand.

I/F ID	Interface Name	Protocol	Source System Component	Target System Component	Data	Interface Purpose
IF08	**UK Power Networks' Planning Data**	File	Outage Planning	DERMS (via ESB)	Outage lists	This data is used by the DERMS to calculate long term sensitivity maps of services.
IF09	**National Grid Static Data**	Web-Services	National Grid's EMS	DERMS (via ESB)	DigSILENT model, ratings, electrical changes, and other services procured by National Grid	The DERMS will relay this data to PowerON to feed into the network model.
IF10	**National Grid Planning Data**	Web-Services	National Grid (Exact system to be determined in detailed design)	DERMS (via ESB)	This include outages in the area, possible reconfigurations and wind forecasts	The DERMS will use this data to calculate long term sensitivity maps of services (and for load flow calculations in the case of wind forecasts)
IF11	**Regional Network Connectivity Model (Base Case)**	To be decided	PowerOn	DERMS	This is the network connectivity model from PowerOn in CIM format	Data will be used by the DERMS to perform load flow calculations.
IF12	**List of Contingencies i.e. Switching States Scenarios**	File-Based CSV Format (short term), longer term Open Standard based format such as CIM	UK Power Networks' Contingency Analysis Process – File created manually	DERMS	ZIV to analyse this to confirm any issues	A Contingency List will be produced by UK Power Networks which might have 50 Points, which DERMS will need to study before it commits future capacity.

Table 4: Data interfaces and communication protocols in Power Potential (Forecasting and Future Availability)

I/F ID	Interface Name	Protocol	Source System Component	Target System Component	Data	Interface Purpose
IF13	**DER procured availability**	Web-Services	DERMS (via ESB and UK Power Networks' API management gateway)	DERs (web app)	Procured Availability	After the auction DERMS will send to DERs their procured availability (production schedule)

I/F ID	Interface Name	Protocol	Source System Component	Target System Component	Data	Interface Purpose
IF14 [44]	**National Grid Dispatch Signal/Instruction**	IF14a:Web-Services. IF14b:TBD	PAS	DERMS (via PowerOn)	Service instructions at the 400 kV delivery point (grid supply point)	The DERMS will use these instructions to either ready the DERs for dispatch, or to dispatch a requested service it has previously armed DERs for.
IF15	**DER and aggregators Instructions and Control**	IF15a: ICCP. IF15b: DNP3 IF15c: TBD	DERMS	DER/Aggregator Controller (via PowerOn and DER RTU)	Generation control instructions including MW and/or voltage set points.	Instructions to the DERs and Aggregators to provide a certain amount of service response.
IF16	**RTU Measurement and Indication**	IF16a: TBD IF16B: DNP3 IF16C: ICCP	RTUs	DERMS (via PowerOn and DER RTU)	SCADA data. Real time measurement and indication data.	The DERMS will use real time measurement and indication data from RTUs (all substations and DER points of connection in the project trials area) for load flow calculations.
IF17	**Regional Network Connectivity Model (Real Time Model)**	ICCP	PowerOn	DERMS	Real time network state (circuit breakers and switches states)	Data will be used by the DERMS to perform load flow calculations in the Service Module.
IF18	**Measurement, Indication and Control**	ICCP	National Grid's EMS	DERMS (via PowerOn)	SCADA data. Real time measurement and indication data.	The DERMS will receive real-time switch and analogue (measurements) data (at 400 kV level) from National Grid to use in load flow calculations.
IF19	**ANM data/signals**	To be decided	UK Power Networks' ANM (via ESB)	DERMS	ANM data/signals	Data will be used by the DERMS to use in load flow calculations and for DER control instructions in the Service Mode.
IF20	**Aggregated Settlement**	Web-services	DERMS (via ESB)	NG PAS	Bid settlement information	Settlement dataset (aggregated – response at 400 kV delivery point level) sent to National Grid to perform settlement with UK Power Networks.
IF21	**Settlement**	To be decided	DERMS (via ESB)	Commercial portal	Bid settlement information	To be used by the commercial portal to settle bids with the DERs and/or Aggregators.

Table 5: Data interfaces and communication protocols in Power Potential (Service Mode)

[44] This National Grid dispatch signal/instruction interface originally was intended to be ICCP connection between PAS and PowerOn. However, design decision has been made to use Web Service interface. The reason being National Grid currently use this type of link with other service provider (e.g. STOR) and using this existing communication method will allow the project progress without significant communication changes to National Grid system.

4.7 Technology architecture for DERMS deployment

The following section provides information on the software and virtual resources required to successfully deploy DERMS in the UK Power Networks IT infrastructure. The resources are estimated based on the computational needs of each DERMS software component to reach the solution and produce results within timeframes defined in the project's confidential non-functional requirements. Modular logical application architecture presented in the Section 4.4 also allows for the easy horizontal scaling, if DERMS is to expand its operation to other GSPs.

4.7.1 Computational resources and operating systems

Table 6 shows operating systems required to set up the environment and virtual resources necessary for the DERMS installation to support computations for four 400 kV delivery points (GSPs):

Component	VMID	VM#	VM_ENV	vCPU	RAM (GB)	Disk (GB)	Description
FEP	FEP	1	Win2016	2	4	256	FEP instance
CIM_CORE + NMM	CIM_CORE_NMM	2	Linux(RHEL)	4	36	2304	CIM Core Server + NMM
Reporting	CR_REP	3	Win2016	2	4	256	Crystal Reports
DERMS_SRV1*	DERMS _SRV1	4	Linux(RHEL)	2	4	32	Service Mode
DERMS_SRV2*	DERMS _SRV2	5	Linux(RHEL)	2	4	32	Service Mode
DERMS_SRV3*	DERMS _SRV3	6	Linux(RHEL)	2	4	32	Service Mode
DERMS_SRV4*	DERMS _SRV4	7	Linux(RHEL)	2	4	32	Service Mode
DERMS_FUT1*	DERMS _FUT1	8	Linux(RHEL)	2	4	32	Future Availability
DERMS_FUT2*	DERMS _FUT2	9	Linux(RHEL)	2	4	32	Future Availability
DERMS_FUT3*	DERMS _FUT3	10	Linux(RHEL)	2	4	32	Future Availability
DERMS_FUT4*	DERMS _FUT4	11	Linux(RHEL)	2	4	32	Future Availability
DERMS_FOR1*	DERMS _FOR1	12	Linux(RHEL)	2	4	32	Forecaster
DERMS_FOR2*	DERMS _FOR2	13	Linux(RHEL)	2	4	32	Forecaster
DERMS_FOR3*	DERMS _FOR3	14	Linux(RHEL)	2	4	32	Forecaster
DERMS_FOR4*	DERMS _FOR4	15	Linux(RHEL)	2	4	32	Forecaster
Totals				32	92	3200	

* 1 instance per GSP

Table 6: Virtual resources and operating system requirements for the DERMS deployment

An example minimum specification for any instance of a single server in this solution is as follows:

- Host Operating Environment: VMWare VSphere 6.5 and Microsoft Azure for some of the DER-facing services;
- Memory: 64GB or more of DDR4 RAM;
- Storage: 4TB or greater 12Gb/s SAS drive; and
- VM OS: Windows Server 2016 / RHEL v7.x.

4.7.2 Redundancy and Back Up

DERMS will be deployed on two server clusters: the main server cluster and a back-up (redundant) server cluster.

Each server in each cluster has the same specification. An overview of the server specification can be seen in the Table 7 below:

Server Name	Server Host Environment	CPU Cores (per server)	RAM GB (per server)	Disk Storage (per server)
Main	VMWare vSphere6.5	14	64	4TB
Back-up	VMWare vSphere6.5	14	64	4TB

Table 7: Main and back-up server clusters' specification

4.7.3 Existing Technology Architecture Impact

No impact is anticipated on the existing technology architecture, except for the purposes of achieving appropriate security architecture, which may involve use of the Microsoft RDS solution to secure some aspects of the solution in relation to the use of Microsoft Azure.

4.8 Security considerations in the project

4.8.1 Security Architecture Risk Assessment

An Information Security Risk Assessment and Management of Information assessment will assist in protection from external and internal threats. This requires security controls to be put in place to ensure the confidentiality, integrity and availability of information assets.

The DERMS solution will comply with information security guidelines, standards and policies, such as ISO27001[45], the Good Practice Guides and more specifically the following policies:

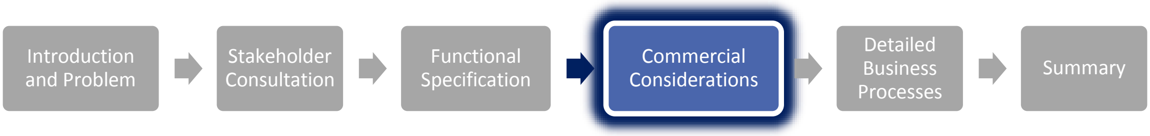
- Access Control Policy;
- Password Policy;
- Remote Working Policy; and
- Data Protection Policy.

As part of the security risk assessment of the DERMS solution various risks were identified. Risk mitigation and control measures were proposed for all risks classed as medium or high, while those identified as low risk are considered for no action.

The detailed information on security arrangements in the project is considered confidential and can be provided to Ofgem on request as a confidential Appendix.

[45] https://www.iso.org/isoiec-27001-information-security.html

5. Finalised Commercial Framework



5.1 Overview of finalised commercial framework

This section shows the finalisation of the commercial framework for the project and the proposition presented to DER. Throughout autumn 2017, the project team has engaged with a number of 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 value of historic reactive power, establishing requirements of 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.

5.2 Payment arrangements

5.2.1 Payment structure

A fundamental principle of the project is that the services will be procured through a market-based solution. As such, DERs will be paid on the basis of 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, as well as transmission-connected assets, to deliver an effective service. National Grid will seek 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, in order encourage business cases to be developed on the representative value of services.

As can be seen from the existing Balancing Mechanism and Commercial Balancing Services, there is a range of payment structures that could be applied for 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 a number of years at a time. The contrasting position would be to procure closer to real-time, offering short contracts briefly before delivery would commence and that 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 ready to deliver MWh or Mvarh for a period of time). Payments can also be made based on capability (reflecting an asset's capability 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 are summarised in Figure 9 below.

	Description in reactive context	Proposal: Model 1 (Single Payment)	Proposal: Model 2 (Dual Payment)	Current practice at transmission level
Availability	Paying to reserve capacity (MWs) so that Mvars are available	×	×	✓ Availability is indirectly paid for through BM re-dispatch
Arming	Paying when the unit is given a target voltage deadband	×	✓	×
Utilisation	Paying when the unit begins to produce or absorb Mvars	✓	✓	✓ Codified formula
Emerging view		• Simplest to access • Flexible – so that National Grid, UK Power Networks and DER are not exposed (e.g. if system conditions change and DER is ineffective)	• Greater certainty of revenue for DER • Aligns with Product Simplification • Buys element of commitment from DER	

Figure 9: Payment Plan

A proposition that included both payments for availability/arming and utilisation, with availability secured at the day-ahead stage, was identified as the most appropriate solution for a number of reasons:

- 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 hence increase confidence in the revenue potential and therefore participation; and
- National Grid and UK Power Networks are able to secure volume ahead of utilisation timescales, as payment for availability for service delivery places an element of commitment on all parties involved.

However, it has been noted by some stakeholders that by not offering longer-term contracts it 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.

However, the project remains open to the possibility that further reassurances (through alternative or additional payments, or by offering longer-term volume commitments) may be necessary to encourage wider trial participation. This needs to be considered in conjunction with the principle that this trial should be able to transition to business as usual. As such, we need to consider whether – once the trial phase has ended – the market framework without those additional incentives will be able to maintain the level of engagement required to make the scheme worthwhile.

5.2.2 Approach to under-delivery

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.

In order to maximise learning from the trial, more lenient performance factors could be put in place, to be reviewed once the market is established. For example, would a performance factor of 50% – where participants would receive full payment for services, providing at least 50% of the instructed volume was delivered – alleviate some of the apprehension experienced by participants in unknown markets? Testing this approach within the trials 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%).

5.2.3 Provision of multiple services

Where possible, participants are encouraged to deliver both the reactive and active power services. With regards to compatibility of the project's services and other energy balancing services, analysis suggests that National Grid's Balancing Services are broadly compatible with reactive power services, as Mvars can be delivered without impacting MW output in most circumstances.

For the project's active power service (which may be used for transmission constraint management), there is an increased potential for conflict. For example, Short Term Operating Reserve (STOR) may require a participant to increase megawatt output for national energy balancing, while there is a local need to curtail generation in the project area. Due to potential nullifying actions, if a participant is already available to deliver a National Grid Balancing Service, it may be necessary to restrict the provision of active power service for the project during the trial.

5.3 Market value

Feedback from DERs indicated further guidance was required on the value of reactive power within the project area. At present, reactive power requirements are met by transmission connected generators through the mandatory reactive power market, 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 proposed positioning cost, if a generator's output has to be adjusted in order to deliver the service. The average price paid for this service between January and July 2017 (£4.34/Mvarh) (See Figure 10) was presented to DERs as an indication of the historic price of reactive power in the project area. This should not be interpreted as the minimum or maximum price to be paid for reactive power through the project.

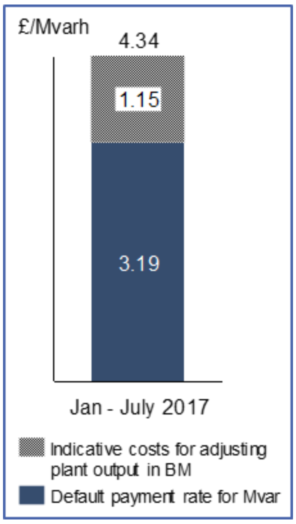


Figure 10: Payment Rate Chart

Feedback through the participant webinar held on 21 September 2017 indicated a number of DER desired further information on the possible running hours and prices for the reactive power service during the trial. The volume of availability and utilisation will depend on both system needs and the cost of alternative actions in the region. However, in order to support the historic price for reactive power, three scenarios detailing actions at GSP level were developed and shared with DER, to provide an indication of frequency of instruction. These are described below:

- Scenario 1: Reactive power service to manage transmission high voltage
  - Utilisation of 100Mvar absorbing at Bolney GSP and 50Mvar absorbing at Ninfield GSP
  - Service instructed 80% of nights all year round, and 75% of weekends between 11:00 and 15:00 when embedded generation suppresses system demand
  - Frequency of instruction: frequent
- Scenario 2: Reactive service to manage a transmission voltage export constraint
  - Utilisation of 10Mvar producing at Bolney GSP, 10Mvar producing at Ninfield GSP, and service armed to inject producing Mvars following a voltage deviation
  - Service driven by outages on the transmission system and by interconnector flows on the South coast
  - It is anticipated that the service would be instructed during times of peak system demand when interconnectors are flowing full into the GB system
  - Frequency of instruction: infrequent
- Scenario 3: Active power service to manage a transmission thermal constraint
  - Instruction to curtail active power to manage flows on the transmission system so they remain within acceptable asset short term ratings
  - Requirement for the service is driven by planned and unplanned transmission outages and existing and future interconnector flows and exports from the DNO network
  - One example of an instruction could be to curtail 100MW from Bolney GSP when export levels on the south coast exceed transmission asset short term ratings
  - Frequency of instruction: infrequent

Whilst it is not possible to provide certainty on the design of the 'business as usual' approach to procuring reactive power and constraint management beyond December 2019, DER have been informed that there will be on ongoing requirement for these services in the project area.

5.4 Commercial data and financial flows

The flow of information from bid submission through to data stored for settlement is shown in Figure 11

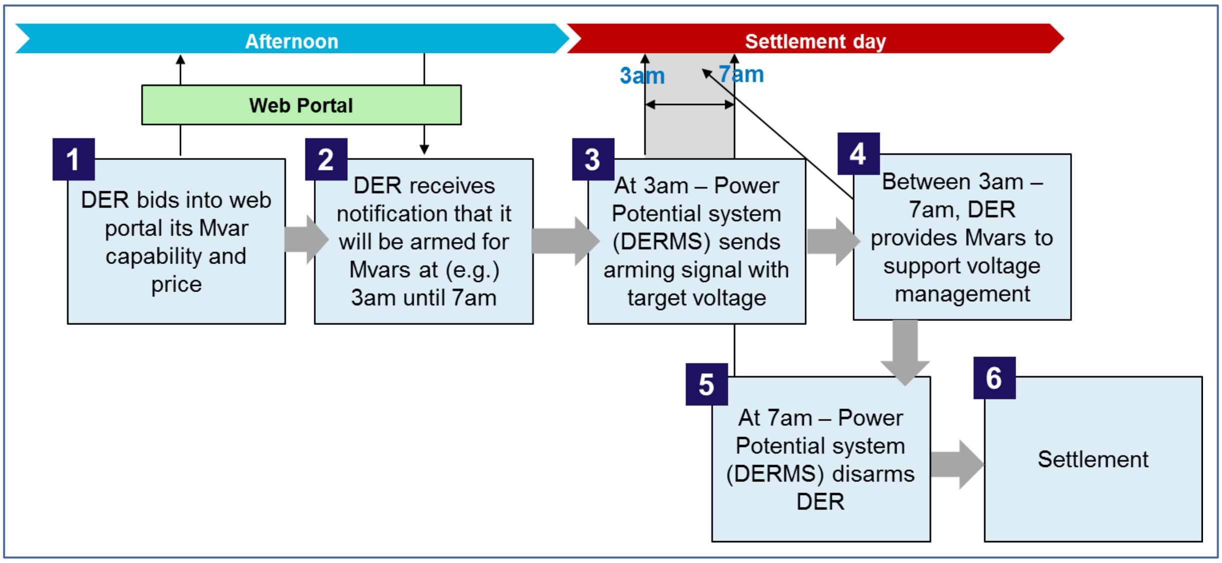


Figure 11: Commercial data and financial flow

A detailed breakdown of commercial flows can be found in Appendix B. At a high level, this comprises the following steps:

- Pre-tender qualification: as well as validating that DER participants are able to provide the required services as part of pre-qualification, the DERMS will be populated with technical data regarding the assets (e.g. maximum capabilities);
- Bid submission: DERs submit bid prices and volumes for each service in which they wish to participate the following day (this can include 'sleeper bids' for participants who do not wish to amend their bids frequently);
- Bid stacking: DERMS collates the bids, accounting for DER effectiveness and any distribution network constraints, and passes the bid stack to National Grid;
- Bid acceptance: National Grid assesses the bid stack against its other constraint management or reactive power options, and (if economic) accepts some proportion of the stack up to 100%, indicating this acceptance to the DERMS, which in turn indicates acceptance to the relevant DER;
- Delivery phase: for the relevant availability window, an instruction signal will be sent to those DERs who are held available, instructing them to a voltage set-point for the reactive power service. For the active power service, a dispatch signal will only be sent when the MW are required;
- Post-event verification: on a monthly basis, DER will provide the DERMS with metering data (or similar) demonstrating their behaviour during the availability windows. In the case of under-delivery, a performance-related adjustment may be required; and

- Settlement and payment: UK Power Networks informs National Grid of any performance-related adjustment, and requests the appropriate payment for the preceding month's services. UK Power Networks then pays the corresponding DERs their payments, accounting for any performance-related adjustments.

5.6 Working with academic partners

Contracts have been signed and delivery is underway with Cambridge University's Energy Policy Research Group and Imperial College to undertake academic research to support the commercial workstream. The deliverables for each contract are described below, identifying how this activity contributes to the project's SDRC milestone reports.

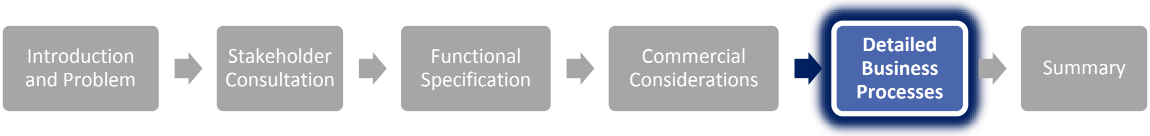
Cambridge University Deliverables
Identification of best practice conceptual market and auction design mechanisms applicable to DER, to inform SDRC9.3
Paper (s) on the Cost Benefit Analysis of the selected trial, to inform SDRC9.5
Final research report

Table 8: Cambridge University contract deliverables

Imperial College Deliverables
Development of the conceptual commercial arrangements aimed at selecting the optimal portfolio of contracts for voltage control and reactive power services from Distributed Energy Resources (DER), to inform SDRC9.3
Evaluating the commercial synergies of conflicts of services for distribution and transmission systems and the market power assessment, to inform SDRC9.4
Validation of the commercial framework for DER services to support the operation of the distribution and transmission networks, to inform SDRC9.6

Table 9: Imperial College contract deliverables

6. Detail Business Processes



6.1 Introduction

This section provides a description of how UK Power Networks' and National Grid's business processes will be affected by the introduction of the service. It also explains the strategy for managing changes and the required training to adapt to new processes and roles.

Figure 12 below illustrates key system interfaces for National Grid and UK Power Networks. UK Power Networks Business Users will use DERMS interface screen to operate and manage the system; whilst National Grid Business user swill use their PAS to communicate with DERMS. Similarly the DER user application(s)/system(s) will be interface with DERMS directly. This chapter identifies which new user interface systems are introduced and any existing systems modified to run the TDI 2.0 solution.

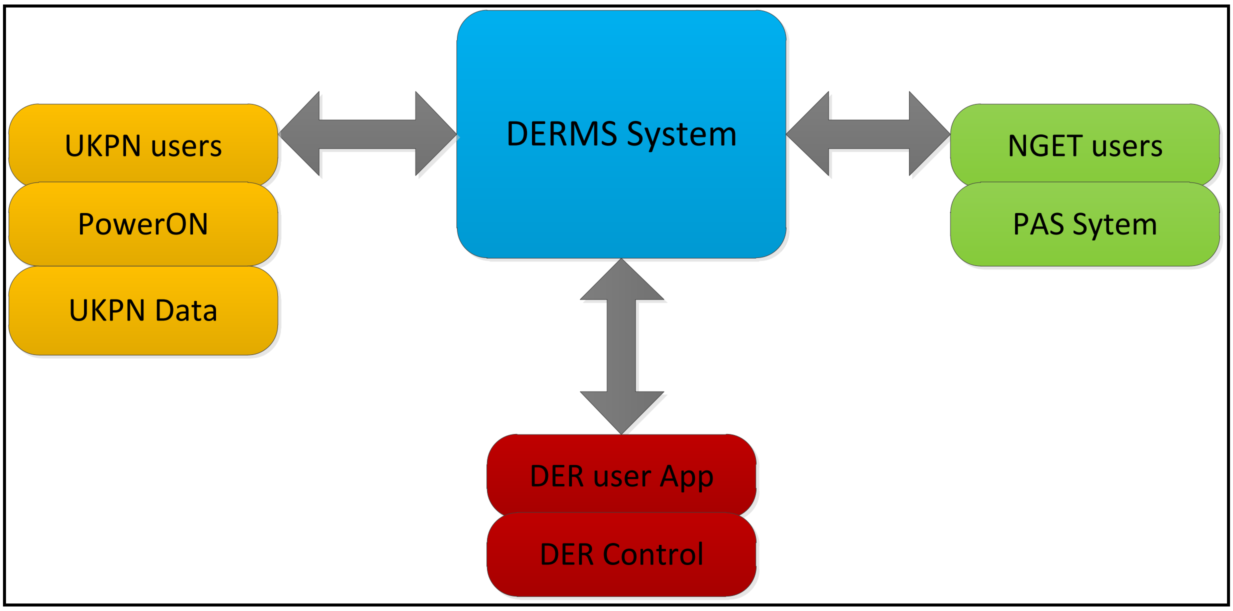


Figure 12: The System and Process Changes

6.2 Impact on National Grid

DERMS will enable National Grid to procure reactive and active power services. In order to interface with DERMS, National Grid will enhance their existing systems called Platform for Ancillary Services (PAS) and Electricity Balancing Services (EBS) as shown in Figure 13. As a result of the project, there will be no change to the organisation structure and no recruitment of additional resources as most of the work is within the capacity of existing roles albeit with some changes. New processes and systems are required while some existing processes and systems will need to be changed to accommodate the project as shown in Figure 13. This illustrates a complete list of new changes or different applications of existing systems and processes.

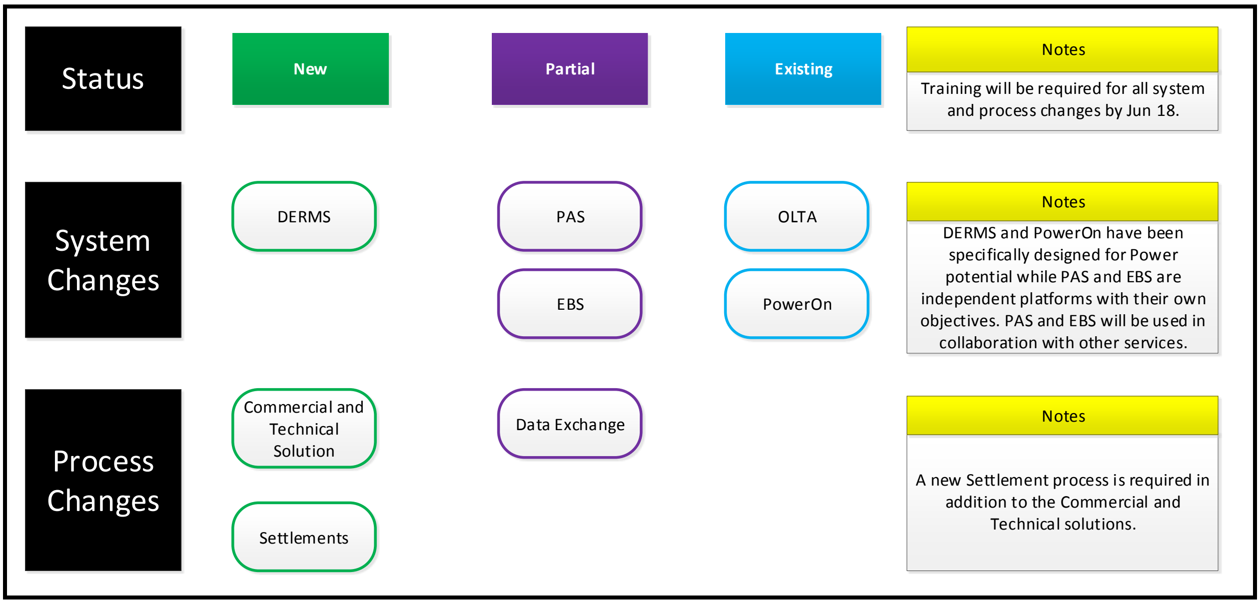


Figure 13: TDI 2.0 Business Process to be changed

Within National Grid, Network Access Planning (NAP) team currently gives advice to the Electricity Network Control Centre (ENCC) on the day ahead basis regarding real and reactive power requirements. The NAP team provides this advice based on existing generators capabilities. Nevertheless, with the introduction of the project the combined service availability and commercial data from DERs will be added to the list of options available to resolve dynamic voltage support and active constraints.

In collaboration with the ENCC Strategy team and NAP planners, National Grid Traders in the Commercial Operations function will review market options once a day at 5pm including the project options presented through the PAS. Traders/ENCC will review the available active and reactive power services offered by DERMS and from other routes to market and procure the required services according to system need. DERMS supports an interactive commercial process which allows DERs participating in DERMS to offer active power services and reactive power services for intervals of four hours for the day ahead. DER offers made in the form of bids are aggregated by DERMS and sent to National Grid's PAS. ENCC will be responsible for arming units via DERMS that have successfully secured reactive power tenders and dispatching contracted active power services through DERMS as required. In accordance with contracted windows, DERMS will put the contracted DERs into the voltage droop mode and assign respective set-points to deliver the instructed reactive power service. For the instructed active power service, DERMS will give an active power set pint to the contracted DERs.

Reactive and active power tenders will be evaluated through the GUI incorporated within the PAS with data transferred from DERMS. The responsibility of contracting services through the project will lie with Commercial Operations function and ENCC. New PAS software with its own objectives and project team is currently being developed as it will be the platform for interfacing National Grid with DERMS and for sending instructions to DERMS. Figure 14 below shows a summary of key departments that will be involved in the solution.

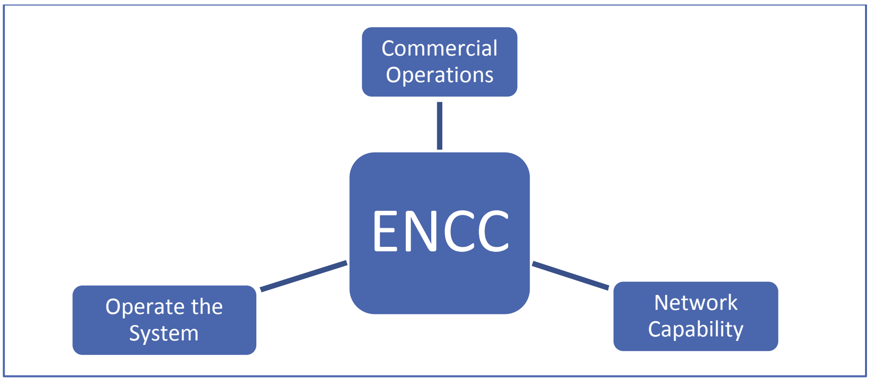


Figure 14: Key Impacted Departments within National Grid

Systems Changes						
Change	**Key Impact & Risks**	**Training Requirements**	**Dependency**	**Value Stream Impacted**	**Roles Affected**	**Level of Impact (High/Med/Low)**
PAS	An internal National Grid system set to go live in Dec 2017, it focuses on procurement of Ancillary services for the System Operator. PAS will connect to DERMS systems to allow for additional procurement of the project's services. Risk is that PAS changes in 2018 do not align with project timescales	Training for Commercial, NCE and OTSE to be done in June to September 2018. PAS project has independent timeline for training which needs to align with this project and ensure all roles are trained on additional usage for this project.	PAS project team, EBS	Commercial Electricity, ENCC, NAP	Energy Traders, Contract & Settlements, Transmission Security Engineer, Assistant National Balancing Engineer	High
EBS	EBS will connect to PAS in order to ensure service despatching feeds into National Grid Balancing Mechanism. EBS is an internal system that is yet to replace all other Balancing mechanism tools. Currently, Mvar capabilities are stored in a database which will be replaced by EBS. The despatch function is yet to be completed so this may impact the project.	Overall EBS training is already in progress. ENCC and Commercial teams will have to be trained on how to update any data and ensure data from PAS feeds into EBS.	EBS Dispatch	NCE (NAP), OTSE (ENCC), Commercial		High

Systems Changes						
Change	**Key Impact & Risks**	**Training Requirements**	**Dependency**	**Value Stream Impacted**	**Roles Affected**	**Level of Impact (High/Med/Low)**
Trading system	Systems not well linked and training not well delivered.	User documentation, training and testing to be carried out by September 2018.	-	Commercial Electricity	Energy Traders	Low
Obligatory Reactive Power Service (ORPS)	Risk is low as this is used to store obligatory reactive power information on contracts and settlements. If used then level of detail would have to be agreed.	Training requirements are low as the team already have an existing process that can be followed depending on the level of data required	-	Commercial Electricity	Contract Managers	Low
GENVARS	The system is currently used to update Mvar capability and would hence need to be updated with the project's capabilities however the system will no longer be in use at the time of the trial. EBS will replace GENVARS database – timescales are being confirmed.	None	-	Network Capability Electricity	National Planners	Medium
Web Interface TOGA/OLTA	Interface already exists however data exchange and timelines have to be defined	Minimal training as there is an existing process	SCADA ICCP links, Grid Code rules	Network Capability Electricity, OTSE	Offline Modelling Engineers	Medium
DERMS	Solution used by UK Power Networks to facilitate DER connected to the network to have potential to provide active and reactive power services to National Grid. DERs, UK Power Networks and National Grid will have to connect their systems to DERMS in order to allow for optimisation and procurement of the project's services.	High level of training is required for all parties using the system.		NGET-Commercial, OTSE (ENCC)	Traders, NBE, TSE	High

Table 10: National Grid System Changes

Process Changes TDI 2.0 Process Reference	Change	Key Impact & Risks	Training Requirements	Value Stream Impacted	# of people impacted	Roles Affected	Level of Impact (High/Med/Low)
52	Service request per GSP	Information exchange through existing ICCP connection	OTSE and NBE training to create Mvar instruction on VPP in PAS	OTSE			Medium
NA	CRAIG Advise	Weekly voltage advice is currently published in CRAIG, this will be done through EBS so the process does not need to be updated for the project. Before trial period and go live, details on the project and resulting changes will have to be published in CRAIG.	None	Control Support & Review	5	None	Low
20	Ancillary services	National Grid must provide other services procured in the area to DERMS through Web Portal/API.. Procurement of services is published in various market information reports however the data may have to be sent from National Grid to UK Power Networks through different means.	Low	Commercial	3	Ancillary Service Analyst	Medium
89	Settlements	Alignment of UK Power Networks and National Grid Settlement.	Medium	Commercial	5	Settlement Analyst	High
4,5	Forecast demand and generation data exchange	Data provision up to two weeks ahead through Web portal/API	Medium	OTSE		Offline Modelling Engineers	Medium
40	Procurement of PP services	NG must decide whether to procure from DERs for next day, 8 hours before delivery day starts.					

Table 11: National Grid Process Change

6.3 Impact on UK Power Networks

The solution will impact UK Power Networks' Control Room, Infrastructure Planning, Outage Planning and IS (Control System Automation team) business areas, it has been identify that UK Power Networks will set up a new business function within the Control Room called DER Scheduling team.

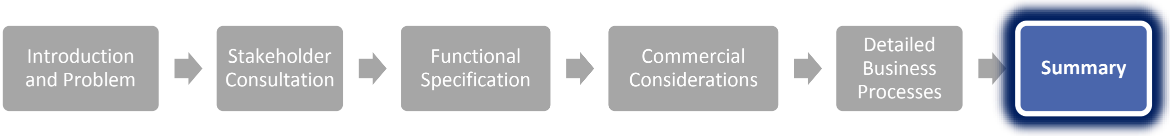
Business Area	Users of DERMS	Responsibility	Other UK Power Networks System effected	Process Changes
Control Room	Hands On	Monitoring Networks	PowerOn DMS	Respond to DERMS Alerts and messages
Infrastructure Planning	Hands On	Utilise DERMS' data for Planning	None	Utilise DERMS data for Planning
Outage Planning	Hands On	Utilise DERMS' data for Outage Planning	None	Utilise DERMS data for Outage Planning
IS	Support	Manage and support IT Infrastructure	None	Support DERMS infrastructure
Control Systems Automation	Support	Support and Maintain network models in PowerOn for the purpose of CIM exports	PowerOn DMS	None
DER Scheduling Team	Active	Operational and day to day management of DERs involvements and ensuring balancing of settlements	None	New function
Finance	NA	Settlement Process	None	Receive settlement reports from DERMS to pay DERs and Invoice NG

Table 12: Key Impact departments within UK Power Networks

As shown in Table 12 above the solution does not require any major process changes for the majority of the teams involved with the project. However, a new function called DER Scheduling Team will be responsible for ensuring that DERMS technically satisfies the capabilities required to fulfil all commercial obligations. This role will also be responsible ensuring that there is enough DER participation to satisfy the active and reactive power requirements on the network. Additionally, this team will also be responsible for validating settlement data and authorising the Finance team to make payments to DERs, along with invoicing National Grid for the service provided. This team will also be responsible for discussing, agreeing and authorising any change required on the DERMS system.

The UK Power Networks project team will be acting as the DER Scheduling team during the trial phase of the solution. For details of the UK Power Networks' business process changes required for TDI 2.0 see Appendix A

7. Summary



In this report, the detail design of the project is summarised and presented. It focused firstly on the stakeholder engagement the project has had externally and internally. It looked at the technical details design to define the key functionalities required by the project in terms of the services and their requirements. The technical design was complemented by the detail commercial framework and business processes that will operate the solution.

A summary of the evidence provided per criteria is summarised in the following sections.

7.1 Stakeholder Consultation and Findings

The project has been engaging with external and internal stakeholders at numerous levels. These engagements has given the project a better understanding of the perspectives of owners and aggregators of different DER types; enabling the project to define in detail the commercial proposition; establishing and communicating the value of historic reactive power; establishing requirements of the DERMS and working with academic partners.

The project, through multiple communication channels, has engaged with numerous stakeholders, more significantly for the project the following two are key:

- DERs within the project's geographic area, including existing energised DERs and prospective DERs with accepted connections. The objective is for the project to continue recruiting additional DERs for the trial period.
- Regional Market Advisory Panel – established as a formal mechanism to engage key stakeholder groups and illicit feedback to inform the future direction and approach of the project.

The project has plans to continue engaging with the industry stake holders and use the learnings and findings to enhance the solution where possible and feasible. Most important is the drive to get a good sample of DERs to support the projects through trials.

7.2 Functional Specification document

The proposed technical solution DERMS will provide the following functions:

- Reactive power service; and
- Active power service

The DERMS software developed by ZIV Automation will be hosted on UK Power Networks' ICT infrastructure. The solution will be integrated with National Grid's PAS and will also communicate with DERs located on the distribution network. Using the distribution network model as source data from PowerOn, the solution will enable the service delivery in two stages:

- The Future Availability Mode would calculate the available capacity across all participating DERs and would present this to National Grid, together with associated costs. Then, National Grid will declare its requirements and secure the active and/or reactive power service(s).
- Real time or Service Mode covers the instruction of services. The DERs in the agreed schedule will be in operation, ready to deliver one or both of the above services when instructed.

Once the DERMS solutions is developed it will be tested and accepted by the project prior to entering the trial phase.

7.3 Finalised Commercial Framework

The project has developed technical and commercial non-built solutions to address transmission constraints and release capacity to connect more DER. As one of the main goals is to create a route to market for DER to provide ancillary services, a commercial framework has been developed in parallel to the technical functionalities to enable the services to be offered to National Grid via UK Power Networks.

The commercial framework in the SDRC highlights the market design approach to create the commercial services; it highlights the roles and responsibilities between actors; and summarises key considerations regarding contract design, value stacking and DER engagement.

7.4 Detail business processes

To operate the solution, there is a need to change existing or introduce new business processes in both UK Power Networks and National Grid.

National Grid's business areas impacted will be Operate the System, Networks Capability and Commercial Operations teams. National Grid will modify their existing PAS and EBS to enable the interface with DERMS. The team(s) will be trained accordingly to efficiently operate the relevant TDI 2.0 function(s).

Similarly, UK Power Networks' TDI 2.0 responsibilities will shared across Control Room, Outage Planning and Infrastructure Planning teams. However, a new role called DER Scheduling Team will created who will responsible for managing the operations of DERMS.

Within both organisations, the business areas that will need a change have been consulted and the project have agreed the process to implement the change. This phase of the project will be implemented well before the trial phase, and is the subject of future SDRCs.

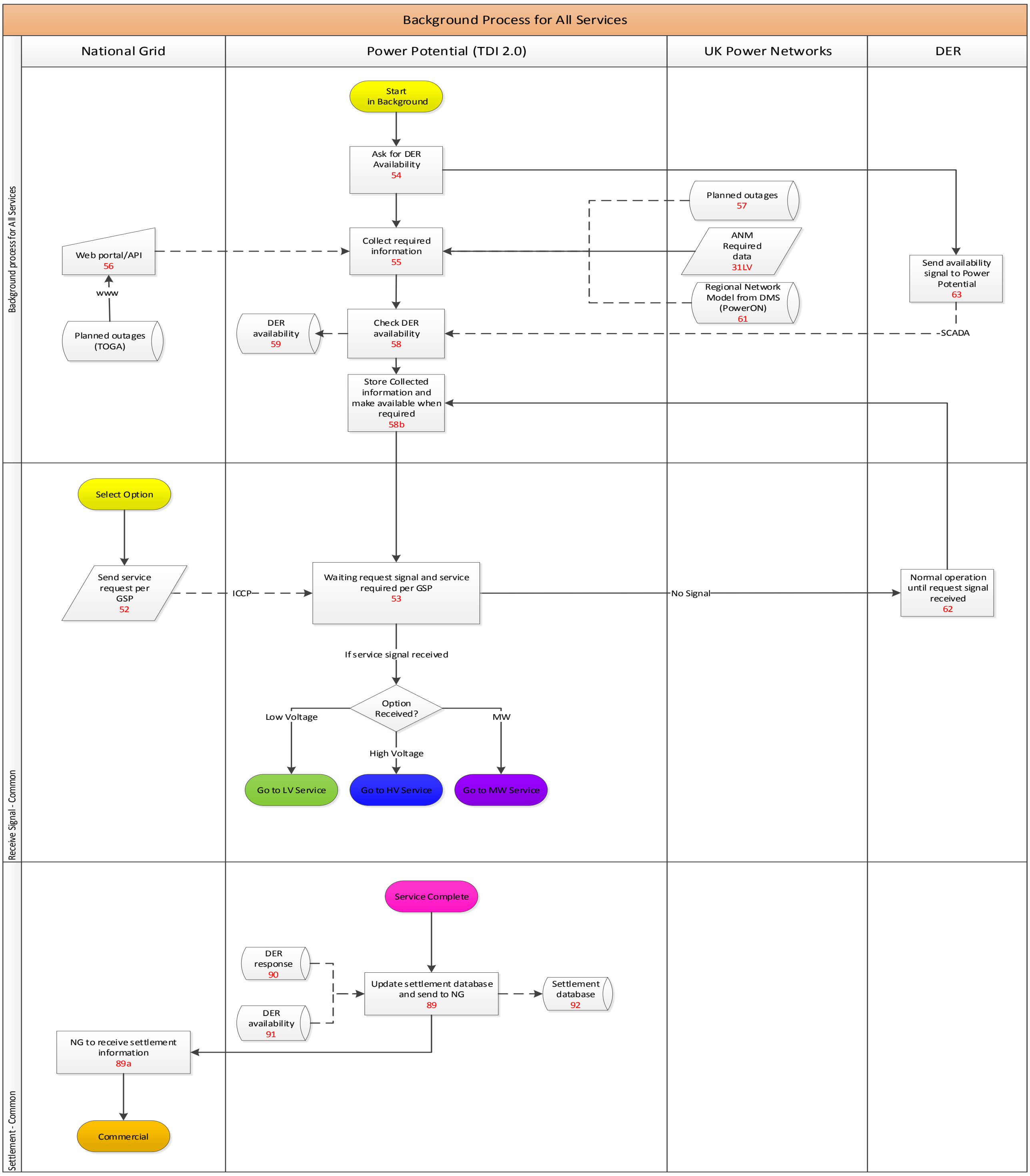
8. Appendix A

Team	Change Name	Type of Impact	Key Impacts & Risks	Communications Requirements	Training Required	Leadership Requirements	Alignment/Collaboration	People impacted	Roles Affected	Level of Impact (High/Medium/Low) Summary of Impact
DER Scheduling Team	Monitor DERMS operations	Process	To ensure DERMS solution continues to satisfy its objectives		DERMS operations	Will be business owner of the solution	Working closely with National Grid and DERs	New Team	New Role	High as this role will be responsible for overall DERMS solution
DER Scheduling Team	DER recruitment and contracts	Process	Need to maintain existing and recruit new DERs into the DER portfolio	DER recruitment campaigns		Will be responsible for maintaining the DER portfolio	Work with Planning and New connections teams. Working with Legal team to define DER contracts.		New Role	High as DER participation is key to the success of the solution
DER Scheduling Team	DER settlement	Process	Validate DERMS settlement and balancing data	Work with Finance team and authorise payments	DERMS Operation	Authority to approve Settlement payments	Work with Finance team	To be confirmed after Trails	New Role	High as the settlements for DER services will need to be accurate
DER Scheduling Team	National Grid Settlement	Process	Validate and ensure that DERMS settlement data accurately reflects amount to Invoice National Grid	Work with Finance team and authorise the invoice amount to charge National Grid for the service	DERMS operation	Authority to raise National Grid invoice	Work with Finance team	To be confirmed after trials	New Role	High as National Grid invoices must balance against service provided

Team	Change Name	Type of Impact	Key Impacts & Risks	Communications Requirements	Training Required	Leadership Requirements	Alignment/Collaboration	People impacted	Roles Affected	Level of Impact (High/Medium/Low) Summary of Impact
DER Scheduling Team	National Grid Control Room	Process	Liaise with National Grid control room to discuss queries, validate unusual requests and notify any situation that cannot be satisfied	Work with NG Control room		UK Power Networks point of contact for all queries	Working with National Grid Control room	To be confirmed during trials	New Role	High as this process will address any issues during DERMS running arrangements
Control	Monitor DERMS	Process	Monitor the network when DERMS is active and react to any alerts or warnings		DERMS operations	None		SPN control team		Low
Control	Liaise with DER Scheduling Team	Process	Work closely with DER scheduling team to realise daily DERMS schedules	Daily DERMS schedule	DERMS operations	None				Low
IS		Process	Support IT infrastructure and schedule routine maintenance				Work closely with DER Scheduling team to agree any downtimes			Medium as DERMS IT infrastructure should be treated as any other UK Power Networks live service

Team	Change Name	Type of Impact	Key Impacts & Risks	Communications Requirements	Training Required	Leadership Requirements	Alignment/Collaboration	People impacted	Roles Affected	Level of Impact (High/Medium/Low) Summary of Impact
Control System Automation	Maintain network information in PowerOn	Process	Maintain National Grid and UK Power Networks network in PowerOn. Mange all changes required.			Owns PowerOn changes	Work closely with DER scheduling team for any outages			Medium as current processes should extend the geographical network boundary to satisfy TDI 2.0
Control System Automation	Support CIM export function	System	Support any queries regarding CIM export of PowerOn network model.			Owns PowerOn	Work closely with DER Scheduling team for any CIM export issues			High as CIM export will be the fundamental input of data into DERMS

9. Appendix B


Background Process for All Services
National Grid
Power Potential (TDI 2.0)
UK Power Networks
DER
Background process for All Services
Start in Background
Ask for DER Availability 54
Planned outages 57
Web portal/API 56
Collect required information 55
ANM Required data 31LV
Send availability signal to Power Potential 63
www
Regional Network Model from DMS (PowerON) 61
DER availability 59
Check DER availability 58
SCADA
Planned outages (TOGA)
Store Collected information and make available when required 58b
Receive Signal - Common
Select Option
Send service request per GSP 52
ICCP
Waiting request signal and service required per GSP 53
No Signal
Normal operation until request signal received 62
If service signal received
Option Received?
Low Voltage
MW
High Voltage
Go to LV Service
Go to HV Service
Go to MW Service
Settlement - Common
Service Complete
DER response 90
Update settlement database and send to NG 89
Settlement database 92
DER availability 91
NG to receive settlement information 89a
Commercial