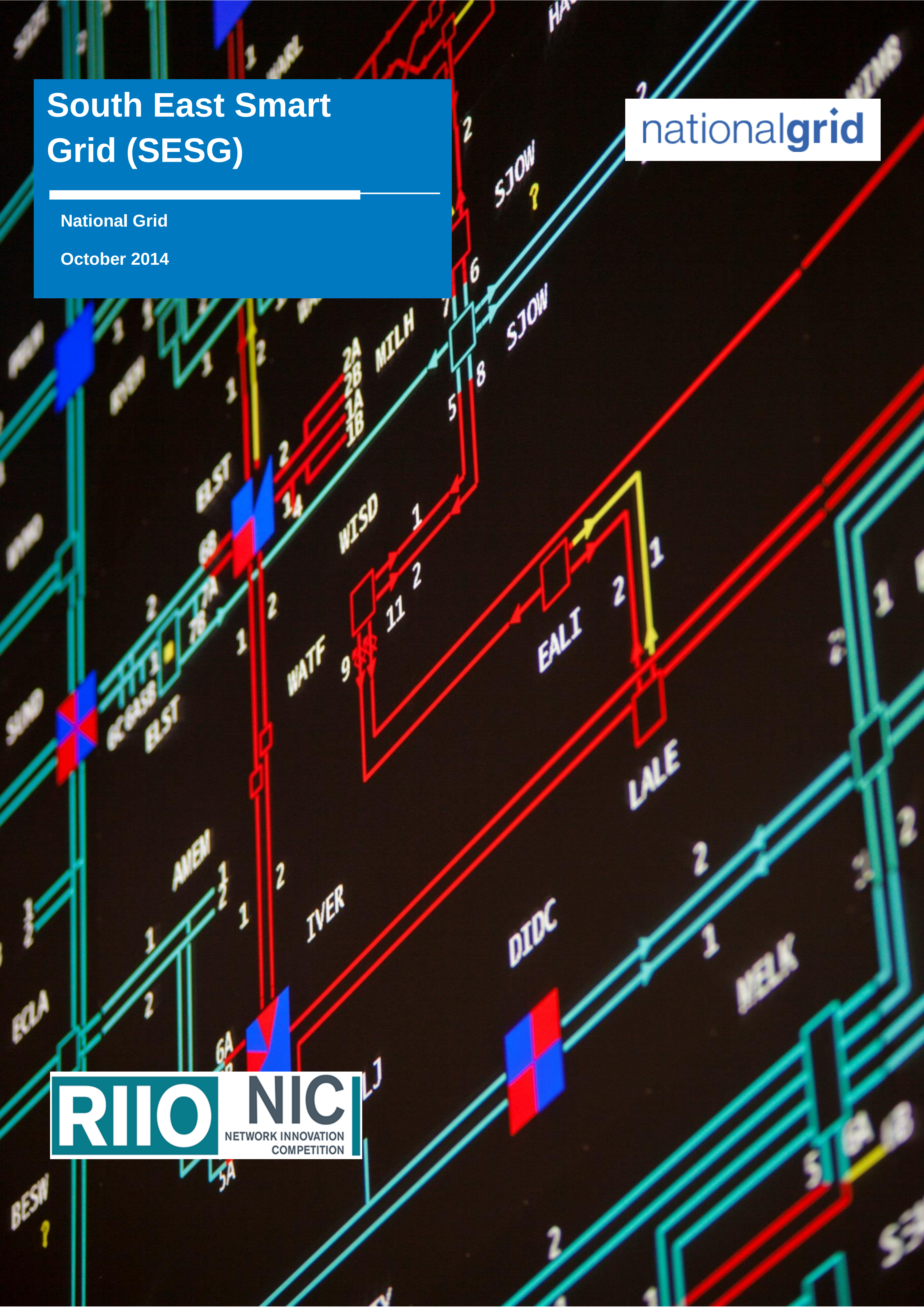
South East Smart Grid (SESG)

National Grid

October 2014



Electricity Network Innovation Competition Full Submission Pro-forma

Contents

Electricity Network Innovation Competition Full Submission Pro-forma

Section 1: Project Summary

1.1 Project Title:

South East Smart Grid (SESG)

1.2 Funding Licensee:

National Grid Electricity Transmission Plc

1.3 Project Summary:

Doubling the size of interconnection capacity between GB and continent could result in £1bn per annum savings on GB consumers' electricity bill through the import of low cost, low carbon energy from Europe along with reduced generation constraint costs. More than half of this potential saving is associated with the interconnectors connecting to the South East region of the network. In addition, National Grid's Future Energy Scenario (FES) has forecast a large volume of Solar PV, onshore and offshore wind farms to connect in this region.

The existing transmission network capability will not allow unrestricted flows across these new interconnectors, further a conventional approach will require major network reinforcement in the form of a new transmission line at an estimated cost of over £500m and a completion date no earlier than 2025. Without a 'smart' approach this will result in delays and constraint costs affecting the benefit to the UK consumer.

The SESG project will seek to develop a new suite of technical and commercial services and/or changes in operational practice through a co-ordinated approach with the distribution network operator to address the network capacity issues. A range of trials will be undertaken to demonstrate the benefits of a coordinated planning between transmission and distribution system, and utilisation of distributed resources (i.e. solar, wind, storage and demand side response) and transmission resources in a coordinated manner.

SESG will provide a pioneering "whole system" method to manage power flows which enable additional capability in the network. SESG will deliver learning and techniques that will be rolled out to other areas of the network and recommendations on how to integrate these with the market.

The project is expected to **start in January 2015 and finish by March 2018**.

1.4 Funding

1.4.1 NIC Funding Request (£k): 9,707.14

1.4.2 Network Licensee Compulsory Contribution(£k): 1,103.52

1.4.3 Network Licensee Extra Contribution (£k): N/A

1.4.4 External Funding - excluding from NICs/LCNF (£k): 795.38

1.4.5 Total Project cost (£k): 11,820.38

RIIO NIC NETWORK INNOVATION COMPETITION

Project Code/Version No: NGETEN02/V2

Electricity Network Innovation Competition Full Submission Pro-forma

Section 1: Project Summary continued

1.5 Cross industry ventures: If your Project is one part of a wider cross industry venture please complete the following section. A cross industry venture consists of two or more Projects which are interlinked with one Project requesting funding from the Electricity Network Innovation Competition (NIC) and the other Project(s) applying for funding from the Gas NIC and/or Low Carbon Networks (LCN) Fund.

1.5.1 Funding requested from the LCN Fund or Gas NIC (£k, please state which other competition): N/A

1.5.2 Please confirm if the Electricity NIC Project could proceed in absence of funding being awarded for the LCN Fund or Gas NIC Project:

☐ **YES – the Project would proceed in the absence of funding for the interlinked Project**

☐ **NO – the Project would not proceed in the absence of funding for the interlinked Project**

1.6 List of Project Partners, External Funders and Project Supporters:

Project Partners

Siemens	(£481.5k contribution)
Imperial College	(£178k contribution)
UK Power Networks	(£97.58k contribution)
Elexon	(£38.3k contribution)

Project Supporters

SP Energy Networks, Western Power Distribution, EDF Energy

All Letters of Support are available in Appendix 8.

1.7 Timescale

1.7.1 Project Start Date:	**1.7.2 Project End Date:**
January 2015	March 2018

1.8 Project Manager Contact Details

1.8.1 Contact Name & Job Title: Dr. Vandad Hamidi SMARTer System Performance Manager	**1.8.3 Contact Address:** B3 – Network Strategy – Transmission Network Services National Grid House – WarwickTechnologyPark – Gallows Hill Warwick – CV346DA
1.8.2 Email & Telephone Number: Vandad.Hamidi@Nationalgrid.com +44-(0)7962-827267	

Electricity Network Innovation Competition Full Submission Pro-forma

Section 2: Project Description

This section should be between 8 and 10 pages.

The SESG project, combines a combination of technical, and commercial innovation activities, and by considering a whole system approach, develops a new system to enable the coordinated use of both the transmission and distribution system and all Users connected to these systems. This will be the key enabler in providing nearly £500m per annum savings for the GB electricity consumers and avoid/defer major investment on the transmission system.

2.1 Aims and Objectives

According to recent analysis, meeting the European Commission's target of having at least 10% of the capacity through cross border interconnection could save the GB consumer up to **£1 billion per year** by 2020 [1]. In order to accomplish this, an additional 4-5GW of European interconnectors would need to connect by 2020. Half of this required European interconnection (2GW) will connect in the South East area of the network.

The South East network is a congested area of the network both in demand and generation, with demand concentrated in the London area and generation in the Thames Estuary. The main interconnectors with Europe, which are located in the region, have a significant impact on power flows in the area. With the imminent increase in volume of interconnection to Europe (Nemo Link and Eleclink), and also increase in intermittent renewable generation such as wind and solar, the resulting operational impact will be the need to constrain the interconnectors in the area to maintain system stability with an increase in constraint costs.

By the time the new interconnectors are expected to connect, the transmission network would not accommodate unrestricted flow across the interconnectors. There will be need for major network reinforcement in the form of building a new transmission line at an estimated cost of over £500m and an expected completion date of no earlier than 2025. Otherwise, to operate the system securely, it is required to either delay the connection date of interconnectors, or limit the power flow across them, both reducing the benefit they bring for the GB consumers.

SESG aims to use an innovative method that brings together knowledge and resources between the distribution and transmission systems in order to better manage power flows and reduce the requirement for constraining generation (in particular interconnection). The proposed method is an application of an innovative smart grid concept, which allows more efficient management of constraints by estimating the system state in real-time, collecting signals from available distributed and transmission resources and taking appropriate and timely action based on system behaviour.

2.1.1 The problems which need to be resolved

The existing South East network has been operating under severe conditions, mainly caused by the fact that the whole south coast is connected by a single overhead line route (double circuit) stretching around 270km, as shown in Figure 2-1. Sellindge and Dungeness substations have experienced most of the operational issues in the region. Historical data and studies carried out by National Grid indicate the need for de-loading the interconnection to France during periods of low demand to mitigate operational risks.

Further contributing to the problem, there is only one major synchronous generation source in the area (Dungeness Nuclear Power Station) to support regional inertia and voltage. This unit may not be running during low demand conditions in the future, further weakening the region.

[1] Getting more connected, March 2014 http://www2.nationalgrid.com/About-us/European-business-development/Interconnectors/

Project Description continued

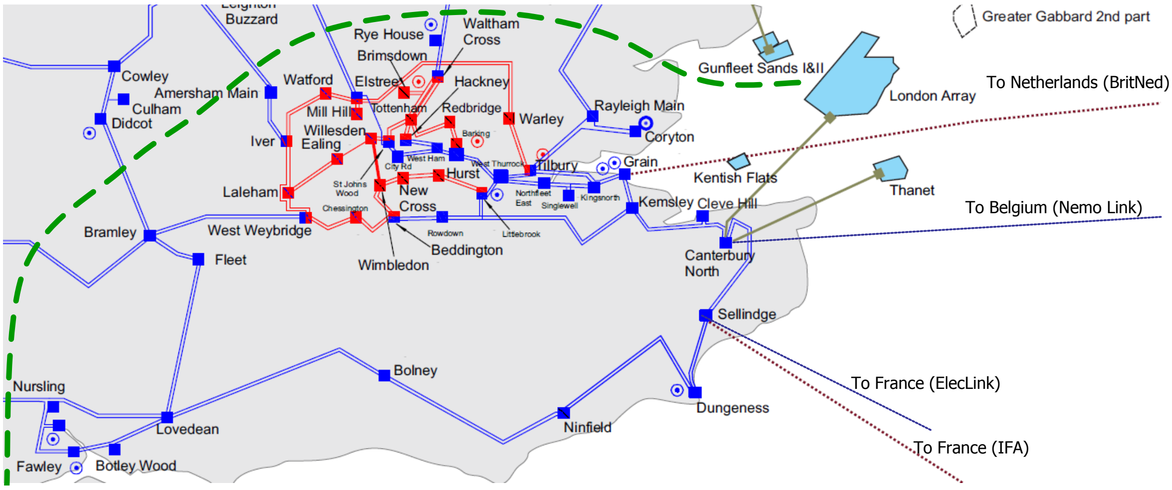


Figure 2-1 The South East Network. The dotted green line defines the area of interest. A more detailed map, which includes UKPN's network, is available in Appendix 10.

Moving forward, National Grid's Gone Green 2014 Future Energy Scenario estimates the following changes in the South East network:

- Additional 2 GW of European interconnectors (Nemo Link and ElecLink).
- Approximately 1 GW increase in solar and wind capacity in next decade.
- Note: this includes distributed generation, i.e. generators connected to the distribution network, rather than the transmission network.

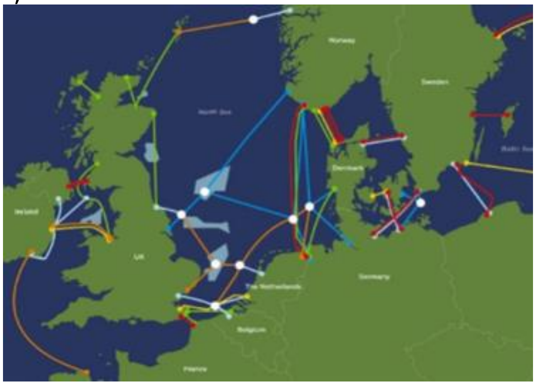


Figure 2-2 Changes in generation background: more renewables and European Interconnection.

These changes in the generation mix will have an immediate impact on network operation, resulting in additional challenges in the South East. These challenges can be summarised in **two main categories**:

1) Power Flow Limitation in and out of the South East Area (as defined in Figure 2-1): The additional installed capacity will cause heavy circuit loading which will limit the amount of power that can flow through the transmission circuits that feed the area.
2) Voltage Management Limitation in the South Coast: As stated, the whole south coast is connected by a single 400kV overhead line route (double circuit) stretching more than 200km. The length of this line coupled with the fact that interconnectors in the area can change their output from exporting to importing has led to complex challenges related to voltage management in the area. Currently voltage is managed through the use of existing reactive support infrastructure connected to the transmission system as well as scheduling response from generators. In the future,

these voltage management issues in the area will be exacerbated due to the large amounts of European interconnectors and intermittent generation (wind and solar) that will connect.

Further detail on network and system challenges of the South East network can be found in Appendix 5.1

2.1.2 The methods being trialled

Whilst there are a wide variety of technical challenges in the South East area, it is possible to summarise the effect of any disturbance arising from any of these conditions and the effect that SESG would have upon this situation in general terms. Figure 2-3 shows the four distinct operational network states (A, B, C & D) which occur before and after any disturbance. As shown in the figure, before a disturbance occurs (state A), the system remains in the 'normal' condition (green region). When the system suffers a disturbance (in state B), a rapid response is necessary in order to return the system to 'normal' (in state C) and further stabilised to reach state D.

Now, the actions taken to stabilise the system after a disturbance (in states B and C) will result in a reduction of the available resources that would respond to a second disturbance. This is depicted in the figure as a reduction of the 'normal' (green) region in state D. As the amount of European interconnection increases, the range of states the network may operate in grows and SESG will act to avoid operating in an unsafe condition. Distributed resources will be used to tackle each of these network states. Full detail on this, including a description of the types of resources to be used by SESG is available in Appendix 5.3.

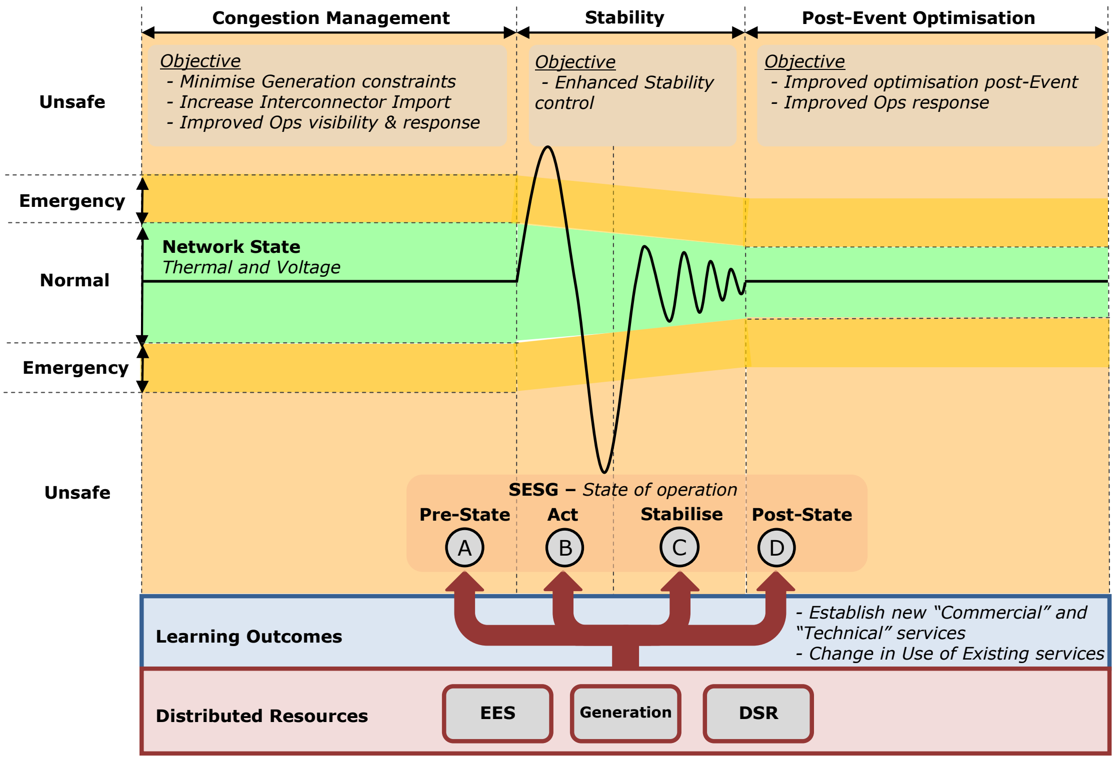


Figure 2-3 Network Operating States (Thermal and Voltage)

All these network states (A, B, C and D) are tackled in the SESG project through a series of work packages, as shown in Figure 2-4. Refer to Appendix 5 for detailed explanation on how SESG adds value to each network state.

Project Description continued

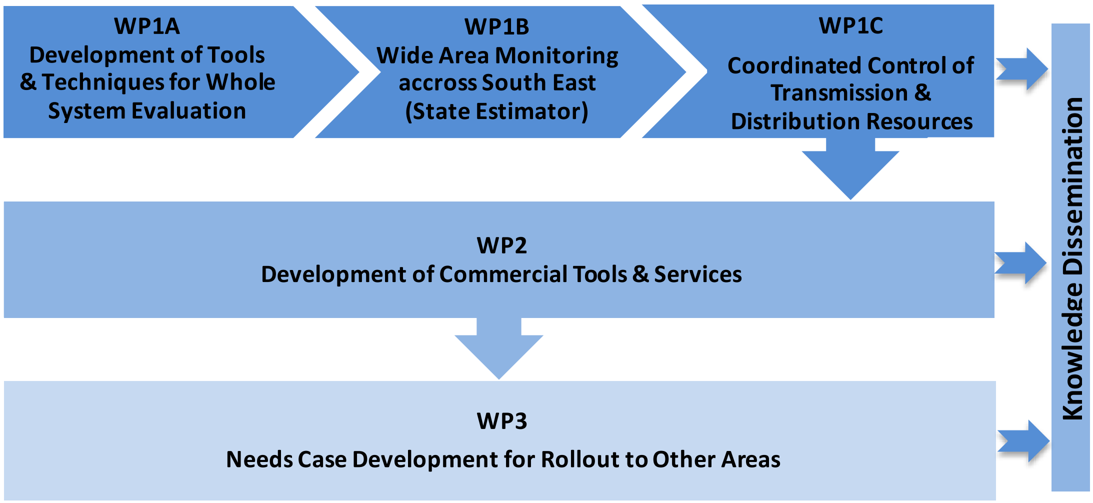


Figure 2-4 SESG Approach

2.1.3 The Development or Demonstration being undertaken

From these work packages, there are five stages considered for demonstration:

Stage 1: Demonstration of a whole system approach in modelling and development of need case for smart solution

- With our academic project partner; Imperial College of London, we will develop the necessary tools and techniques to enable application of wide area monitoring and control, and response from transmission and distribution resources to manage network constraints.

Stage 2: Demonstration of a Wide Area Monitoring and Control (WAMC) on transmission and distribution system

- With our project partners; Siemens and UKPN we will develop a pilot scheme of monitoring, command and control system in the south east to estimate system parameters in real time, and enable both open-loop and closed-loop decision making.

Stage 3: Demonstration of co-ordinated response from transmission and distribution connected resources

- With our project partners; Siemens and UKPN, we will test and evaluate responses from all available resources from both transmission and distribution system under different system conditions. The resources we expect to perform this demonstration on include demand side response, energy storage, embedded generation.

Stage 4: Demonstration of innovative commercial services to incentivise the service providers to participate in the new market

- With our project partners; Elexon and Imperial College of London, we will develop new commercial services required to ensure this can be commercially viable under a business as usual.

Stage 5: Development of a non-build solution using both commercial and technical knowledge of the project for immediate roll out

- With all the project partners, we will develop a non-build solution under the network development policy for roll out to other parts of the network.

2.2 Technical Description of Project

SESG will be delivered through a number of related work packages. These are described here with particular reference to their innovative nature. The technical description is included in Appendix 5 in more detail.

WP1A – Development of Tools and Techniques for Whole System Evaluation of Smart Solutions

The SESG project requires interaction between transmission and distribution resources. Due to the complexities of this interaction, models from the distribution system will need to be analysed in combination with those in the transmission system in order to understand the level of response that may be available at both transmission and distribution network level.

Imperial College will perform extensive analysis and computer simulation studies of the South-East network (at both transmission and distribution levels) to determine the appropriate monitoring locations, validate the effectiveness and benefits of coordinated control within both transmission and distribution networks. The key task will include

- T1.1: Development of computer simulation models of the South East network
- T1.2: Identification of optimal locations for installing monitoring devices
- T1.3: Development of Virtual Power Plant concepts to enable flexible resources in distribution networks to support control of the South East transmission network
- T1.4: Investigation of coordinated control strategies in collaboration with Siemens and validation of the control platform through computer simulation

Alongside computer simulations, real-time hardware-in-loop (HIL) simulations will be performed at the Maurice Hancock Smart Energy Laboratory at Imperial College. The dynamic behaviour of the South-East network will be emulated in real-time with a combined HIL scaled physical models of relevant elements of the South-East system, and in particular the VSC- HVDC converters (the technology envisaged to be used for new HVDC interconnectors). This will incorporate simulation models of the network running in a real-time power system simulation platform, Opal-RT interfaced to the physical platform using a power converter acting as a power amplifier. The real-time controller will be implemented in a rapid control prototyping (RCP) platform from Opal-RT. The control hardware will receive measurement signals from a real-time network simulation platform and issue control commands back to it the same manner as the SESG Central System Monitoring would do. Further detail on this may be found in Appendix 5.4.

The main tasks to be undertaken are:

- T1.5: extend the existing real-time network simulation platform to simulate the behaviour of the South East network in real time
- T1.6: integrate the physical hardware (converters for interconnectors, aggregated storage etc.) with the real-time network simulator to create a hardware-in-loop simulation environment
- T1.7: validate coordinated control strategies with real-time hardware-in-loop simulation

The real-time hardware-in-loop simulation facility will enable Imperial College to validate and the monitoring and control algorithms to be trialled in this project (under WP1B and

WP1C) and investigate potential improvements and/or generalisation for wider roll out elsewhere (WP3).

The output of this work package will provide the information required for the next work package on the level of monitoring on the network (at transmission and distribution) such as which Grid Supply Points (GSPs) will require monitoring devices as well as the level of response required from the distribution network for each GSP.

Innovation: Development of the models, and control algorithms required for development of WAMC on transmission and distribution network, as well as regional response estimation (at different GSPs).

WP1B – Wide Area Monitoring across South East (T&D State Estimator)

Knowing the network status in real time prior to taking any operational actions will be crucial in order to make operational decisions. Conventionally, operational actions are planned based on historical data, engineering judgment or the generation/demand profile of the network. However, in a congested, weak network with considerable volumes of intermittent generation, the system operator needs to take actions in a more critical time scale, in order to ensure fully optimised, economic and efficient operation of the network.

To achieve this, the operator will need greater level of real-time visibility of the network. Hence, there is a requirement to develop system wide area monitoring and control (WAMC). In the first instance, existing measurement/control units will be examined to discover if they could be suitable for the purpose of smart grid deployment and where necessary, additional equipment will be installed for monitoring to the transmission and distribution network. The analysis and simulations carried out by Imperial College in WP1A will inform WP1B by identifying most appropriate sites for monitoring.

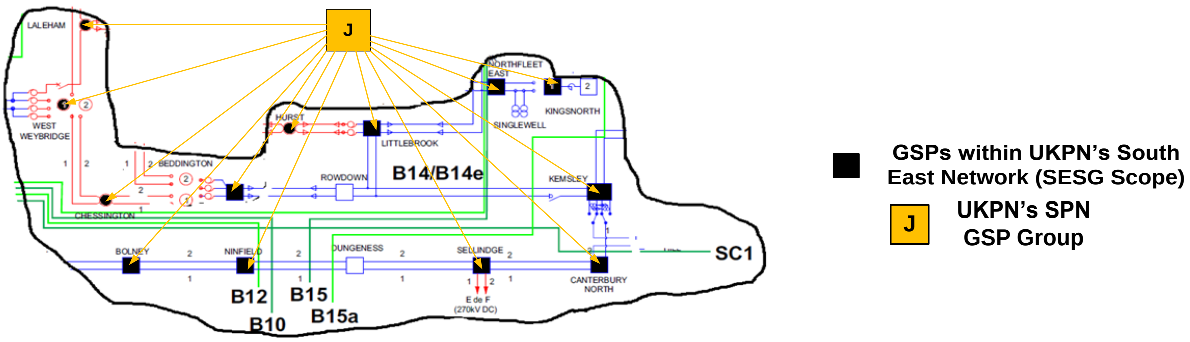


Figure 2-5 UKPN's SPN Grid Supply Points with Transmission Boundaries

Figure 2-5 shows the 13 GSPs that fall within UKPN's SPN region as well as the system boundaries that may directly affect this region. The WAMC enhances NG's visibility of which GSPs can help in managing the constraints and enable performing necessary control (either autonomously by the control system or with operator's instruction) at GSP level to instruct the response to be delivered at the GSP level. The analysis and simulations carried out in WP1A will inform WP1B by identifying most appropriate sites for monitoring. Through this approach, the aim is to transform the traditional, manual control system of the South East region into an automated, modern smart grid enabling the use of distributed resources such as DSR, storage and embedded generation to manage constraints.

Innovation: The existing system monitoring is limited to either transmission or distribution level. Therefore, there is a lack of a comprehensive real-time monitoring system to evaluate the whole network status in one picture. SESG utilises an innovative method for system

Project Description continued

monitoring using all available system monitoring devices to ensure measurement will be taken from the optimum location and with high resolution (time scale) for real-time applications.

WP1C – Coordinated Control of Transmission and Distribution Resources

The interaction between transmission system equipment and distributed resources shall be investigated. A smart co-ordination of distributed resources (such as DSR) with transmission resources may defer or even avoid the need for building of new infrastructures. The methods used makes the best use of transmission and distributed resources. For example, voltage depression resulting from south east interconnectors when they are on importing mode could be managed by appropriate demand side response.

Developing a suite of technical and commercial services by utilising both transmission and distribution resources in South East is the main deliverable of SESG. Devices such as solar PVs, DSR and storage units are available to assist the system operator in managing the operational challenges listed in section 2.1.1. This work package will demonstrate how these units can be controlled and managed by the WAMC tools developed in WP1B. An important innovation of SESG is that the DNO should be able to monitor/command the distribution resources in real time based on transmission system requirements. WP1C trials innovative control methods which will be replicable in other areas within the network to manage the network constraints (as listed in Section 2.1.1) using a whole system approach.

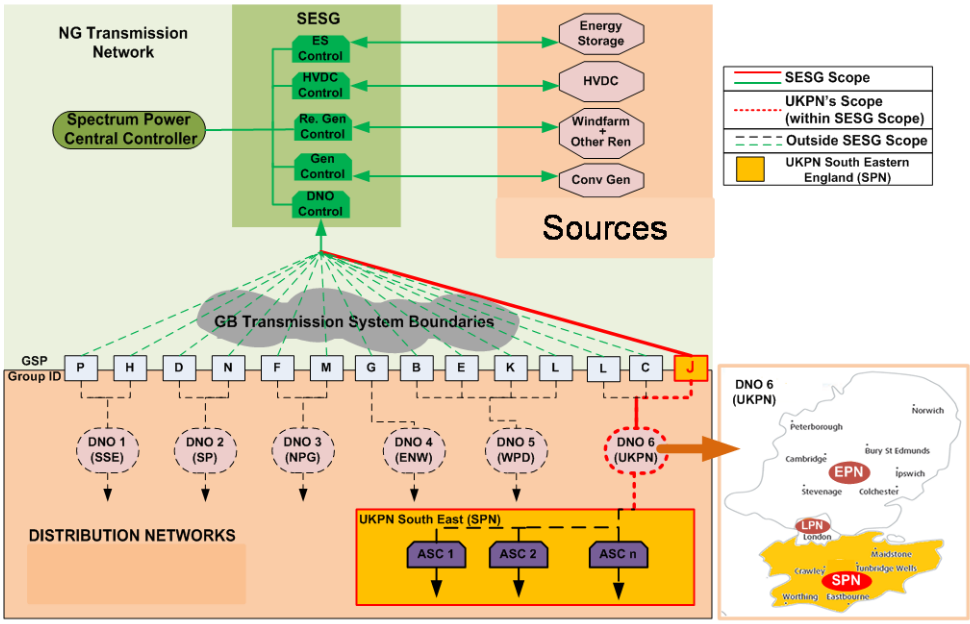


Figure 2-6 Proposed overall system architecture.

The diagram in Figure 2-6 is an overview of Siemens' proposed solution architecture that will meet all of the objectives of the SESG project. The proposed solution uses a central intelligence (physically located at NG's data centre buildings in Warwick/Wokingham) to deliver flexible, scalable and expandable intelligence through an active interface with the transmission actors. The proposed spectrum power tool also has an important capability of optimal dispatch to balance active demand with dynamic generations. The tool centrally monitors and controls all of the Energy Storage (ES), HVDC, Renewable Generations (Re. Gen), Conventional Generators and relevant DNO equipment that are connected to NG transmission network.

The Grid Supply Point (GSP) serves as an interface between National Grid Electricity

Transmission (NGET) and DNO's network. These are grouped at a high level into specific regions and DNO's. Figure 2-6 shows all of the 14 high level GSP Groups and GSP group J which is relevant to SESG project and is part of UKPN's SPN network. Hence all control actions that will be performed by the SESG will directly and only affect GSP J and the 13 sub-GSPs shown in Figure 2-5. All other GSP's are outside the scope of the SESG project.

Our academic partner will support validation of the coordinated control schemes using the real-time test facility (described under WP1A). For the interconnectors, offshore wind farms and aggregated storage, scaled-down physical hardware set-ups would be used in the validation exercise. Other resources would be included within the network model running on an Opal-RT simulator. The coordinated control strategies would be implemented within a rapid control prototyping control (RCP) platform from Opal-RT with an interface between the system emulation and RCP platforms.

<u>Innovation:</u> The demonstration of the control system capable of estimating the resource required at different GSPs, to coordinate the over level of response from transmission and distribution connected resources.

WP2 Development of Commercial Tools and Services

The roll out of the commercial tools and techniques developed as part of WP1 to other parts of the network under a business as usual requires both technical and commercial innovations. The technical aspects of the coordinated approach in managing the network constraints will be developed as part of WP1. The WP2 focuses on the type of commercial services which enable the use of such concept as an alternative to investment in building new transmission infrastructure. This activity will be carried out by Elexon and Imperial College and will result in developing proposals for new market signals (through new commercial services) for a range of service providers. These new commercial services will be valued based on the knowledge gained in WP1 and cost of network investment which will ensure an economic and efficient solution is developed.

The service providers which are capable of providing the response to the grid (at transmission or distribution level), require commercial incentives. There are currently gaps in the commercial services available in order to roll out the non-build solution concept relying on coordinated response from transmission and distribution resources. In this work package, we will develop such services which require a careful assessment in terms of comparison against conventional solutions, duration of the service contract, payment mechanism (availability + utilisation), avoidance of conflict/duplication of services, etc. To address this, Imperial College will carry out comprehensive analysis of the option value of such contracts for both Transmission and Distribution networks (T2-1). This will require coordination between Transmission and Distribution network operators to ensure that the DER offering services will be able to support transmission network whilst respecting the distribution network operating constraints and limits.

<u>Innovation:</u> The incentives to be provided to service providers require a detailed assessment of the long term benefit of such services, against constraint cost, and cost of the conventional solutions. These new commercial service will enable development of non-build solutions providing greater value for the consumers.

WP3 Need Case Development for Rollout to Other Areas

The amount of knowledge developed in the previous work packages will be captured in WP3 to develop a need case for rollout of the project to other areas of the network. This involves demonstration of potential value of the technical and commercial tools to become a business-as-usual tool under network development policy.

The potential for rollout to other parts of GB is massive, considering the expected growth of embedded generation (one of the types of distributed resources used in SESG). Northern England in particular is expected to see even higher rate of growth of embedded generation than the South of England and will also face similar challenges in the future due to new HVDC connections post 2020. Refer to Appendix 5.5 for more information on this.

The roll of the concepts developed in the SESG to other parts of the network which without investment may impose constraint cost, or delay in connection of interconnectors, requires development of the concept as a non-build solution under the network development policy. This work package develops this solution (which will include identification of risks and opportunities), which will then be considered as part of future cost-benefit analysis carried out to justify network investment in conjunction with conventional solutions.

Innovation: The non-build solution within network development policy (based on least-regret approach) which enables the network development teams to consider as economic and efficient solutions. The activities as part of WP3 ensure the opportunities, and enabling measures for the successful roll out of the concept are developed so they can be implemented without delay.

2.3 Description of design of trials

The solutions developed in each individual work package of SESG will be validated through the following trials:

WP1A (Technical) - Development of tools and techniques for whole System evaluation

The joint models from transmission and distribution systems which allow the trials to be tested first, will be developed at this phase. The models enable studying the behaviour of transmission and distribution resources, to determine the potential for using distributed resources to manage transmission constraints in the South East region. This will keep feeding back to the model so that it is as robust as possible by the end of the project. Real time demonstration will also use the flexible test platforms available at the Maurice Hancock Smart Energy Laboratory at Imperial College. The lab has been developed around rapid-prototyping power converters for testing smart grid controllers and devices for low voltage applications with physical models of transmission lines and cables. That has been augmented with two scaled models of multi-modular VSC-HVDC converters, with a third model with embedded energy storage being commissioned. These converters use the same topologies applied by the major VSC-HVDC manufacturers and can effectively replicate the behaviour of these systems.

The system simulation platform will combine hardware-in-the-loop (HIL) scaled physical models of relevant elements of the South-East system, specifically the VSC-HVDC converters, with complex high order simulation models of the power system running in real-time power system simulation hardware such as Real Time Digital Simulator (RTDS) interfaced to the physical platform using a power converter acting as a power amplifier. Please refer to Appendix 5 for more details on the work Imperial College would carry out.

WP1B (Technical) - Wide Area Monitoring across South East (State Estimator)

The first implementation stage of the SESG will involve the creation of a monitoring and control centre for the South East area, as well as the installation of system monitoring devices in the South East area. This centre, located at NG's data centre buildings in Warwick/Wokingham, will collect the signals from the monitoring devices, the control units and the distributed resources. System monitoring devices will provide real-time measurements of system variables on key nodes of the network to the central monitoring system (some of these devices have been used in Humber Smart Zone). Once the devices are installed, appropriate tests such as latency of data signals will be carried out.

The accuracy and reliability of the state estimation algorithm will also be validated. The number of system monitoring devices installed is expected to be sufficient to provide redundancy to estimate the most relevant states of the system. Thus, a selection of the available signals could be used for the estimation algorithm, whereas the remainder of the available signals could be used to compare the estimated values against the actual values measured in the system. This scheme would be allowed to run for an extended period of time to capture valuable data to assess the adequacy of the model under a range of system conditions.

The level of redundancy provided by the installed measurement devices will also be evaluated based on comparing the accuracy of the estimated voltage stability margins obtained using different sets of real measurements as opposed to using simulated measurement data. This analysis will provide valuable information about the effectiveness of the installed PMUs and provide insight on the areas of the grid that may require additional measurement deployment.

WP1C (Technical) - Coordinated Control of Transmission and Distribution Resources

One of the key innovations of SESG is the coordination of large-scale actuators in the transmission grid (HVDC converters, SVCs, etc) with the different resources in the distribution network (demand side response, embedded generation, and energy storage).

A series of tests will be performed at different levels to showcase the ability of these resources to provide the desired action in response to instructions sent by the state estimator. Tests will be carried out at different levels of aggregation. To conduct such tests, the control centre will issue commands to produce different types of responses (active power absorption reduction, reactive power injection, etc.) under different scenarios (peak demand, low demand, high wind, high solar PV production etc.). The information obtained from these tests will play an important role in WP2 as it will be used to adjust and to validate the resource models developed.

WP2 (Commercial Innovation) - Development of Commercial Tools and Services

The new commercial services which will be developed enable providing right level of incentives for the services required for the SESG. The trial at this stage will mainly be focusing on the interaction of such new services with existing commercial services.

WP3 (Commercial / Technical) Needs Case Development for Rollout to Other Areas

In WP3 the new non-build solution as part of network development policy will be trialled and the roll out mechanism, and approach for such concepts across the system will be evaluated.

The trials proposed will be conducted with prior arrangements and agreements from UKPN and National Grid. NGET as System Operator is fully committed to allow the trials to take place, and given the nature of trials, they will not cause any implication to continuous day to day operability of the system. The project has been agreed by National Grid's System Operator function where both Directors of Market Operation, and Transmission Network Services have approved the full programme.

2.4 Changes since Initial Screening Process (ISP)

The scope of the SESG project in this document is consistent with the submission for the Initial Screening Process (ISP). However, the following changes have occurred:

- Given the level of preliminary work carried out so far, we intend to **start the project in January 2015**.
- The total cost of the project has been modified to **£11,820.38k**

Electricity Network Innovation Competition Full Submission Pro-forma

Section 3: Project Business Case

This section should be between 3 and 6 pages.

The SESG project will enable a saving of up to £500m per annum to GB consumers by enabling the unconstrained operation of interconnectors in the area.

3.1 Context

As described in section 2.1, doubling the size of interconnection capacity between GB and Europe could **save the GB consumer up to £1 billion per year in their electricity bill** [2]. In order to accomplish this, an additional 4-5GW of European interconnectors would need to be built and connected by 2020 and it is National Grid's responsibility to ensure that these interconnectors can transfer power without constraint, while ensuring the most economic and efficient solution to achieve this. Any restriction in the power flow capability of the interconnectors undermines the financial savings they can bring for the GB consumers.

A significant proportion of these European interconnectors (2GW) will be connecting in the South East by 2020 (Eleclink and Nemo Link). However, the South East network is a heavily congested electricity network with high levels of both generation and demand making it a complex area to manage operationally. With additional interconnection to Europe as well as an expected increase in intermittent renewable generation in the area, the network will be impossible or hugely expensive to manage under current operational arrangements when all projected interconnectors are at their maximum output. The two "business as usual" methods would be to either constrain generation or reinforcing the network.

SESG aims to enhance network capability without the immediate need to build new infrastructure. This will facilitate the integration of European interconnection and renewables without the need for significant reinforcement. The utilisation of smart grid technologies will lead to lower costs, reduced transmission and distribution losses, efficient power production and optimal asset utilisation. These benefits, along with eliminating the requirement for building new assets, will reduce the carbon footprint of the transmission networks while keeping the cost down for the consumer.

In this section we compare the costs and benefits of continuing with a business-as-usual approach, and SESG by considering both short-term and long-term effects of each approach.

3.2 Business as usual

Identifying the future network reinforcement options involves a process as shown in Figure 3-1 below and briefly discussed here:

Stage 1 - Input; Future Generation and Demand Background:

The process starts with studying the future generation and demand, which are scenario dependent, and their impact on the network depending on each scenario will be different.

---

[2] Getting more connected, March 2014 http://www2.nationalgrid.com/About-us/European-business-development/Interconnectors/

Stage 2 - Requirements; studying network capability and required transfer:

Under each scenario, the network capability is compared against the future required power transfer. If the required transfer is higher than the network capability, this is an indication of potential constraint requirement.

Stage 3 - Solutions; and identifying the solutions:

A range of solutions are considered at this stage; starting from the solutions which maximise the use of existing assets, to major reinforcements (i.e. building new transmission line). <u>The non-build solutions (i.e. smarter solutions) are also considered at this stage only if they have been trialled and tested before</u>.

Stage 4 - Selection; deciding on what solutions, and when to implement them:

A cost benefits analysis will be carried out at this stage to compare the constraint costs against the lifetime cost of proposed solutions to ensure that timely investments are made to provide greater network efficiency and value for the consumers.

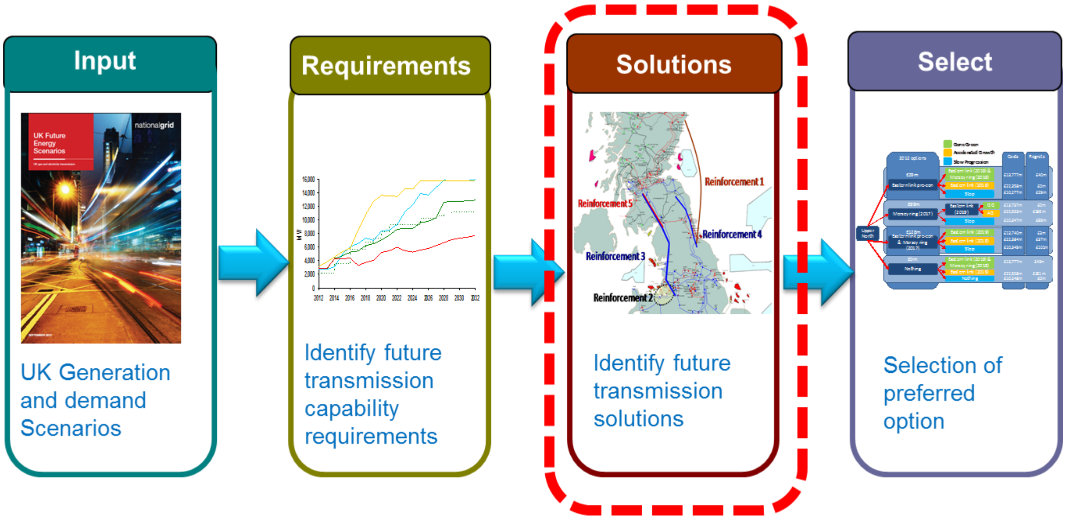


Figure 3-1 Network Development Process.

As it can be seen above, the stage 3 (solutions) is an important aspect as depending on what solution is available to network planners, the selection list of a range of options can be developed. Under a business as usual, given some of the smarter technologies have never had any trials on the network, the options will be limited (and potentially expensive).

As explained in section 2, the operating cost resulting from constraint management in the South East area will make reinforcement an inevitable option. The number of times a year that the South East experiences constraint management due to the interconnector with France, thermal and Voltage Management (London area) is increasing.

Project Business Case continued

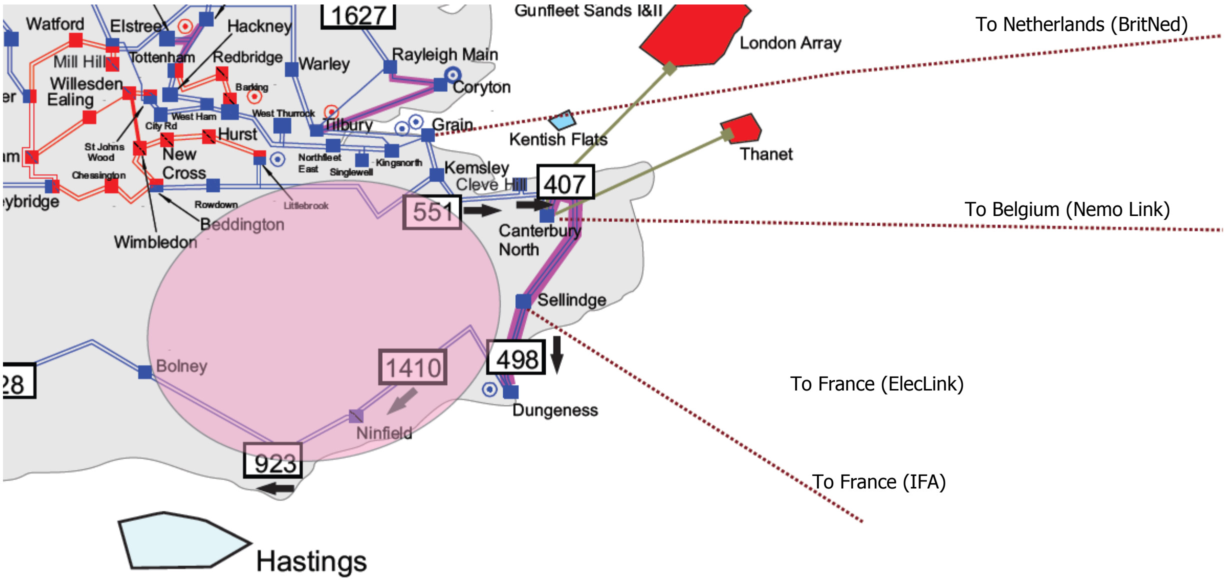


Figure 3-2 South East reinforcement requirements. Source: ETYS 2013 [3].

With more interconnection with Europe the required transfer for the south east increases considerably. The increased required boundary transfer will reach the point that violates the existing boundary capability.

With more renewables- especially solar PVs connections in the south coast the required boundary transfer may be higher and as a result the boundary capability may be violated even sooner than estimated.

The other technical challenge which the network will face in the region is "voltage instability" when the new interconnectors operate at their rated capacity. This is mainly due to lack of major dynamic compensation equipment in this area and a weak network.

Therefore, to manage the network constraints under a business as usual scenario the proposed solutions are:

- Constraining flow across interconnectors;

vs

- Installation of number of reactive power compensation units (i.e. SVC, STATCOM)
- Installation of new transmission line between Sellindge 400kV and 400kV ring around London (i.e. to a substation such as Beddington 400kV or Rowdown 400kV).

[3] Electricty Ten Year Statement 2013. Appendix C – Power Flow Diagrams. http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Electricity-ten-year-statement/Current-statement/

Constraining the interconnectors in the long run will be economically inefficient and ultimately the new infrastructure will be required. This will be an extremely expensive option (i.e. costing around £500m) and with a very long lead time.

3.3 Need for Smart Grid

As mentioned in previous section, the disadvantages of a business as usual process to manage South East's issue are increase in cost for the consumers if conventional solutions are only considered for the network development. It was also mentioned that the new smarter technologies require demonstration first to be fully effective and used as a tool for network planning.

The driver for being economic and efficient, increasing the competition in the market to provide technologies which are unconventional, and maximising the use of resources at both transmission and distribution networks all create the need case for a smart grid.

Smart grid is a secure, economic and efficient and sustainable network planning tool, through advanced automation processes. A more advanced monitoring and control system will enable management of the network at full capacity. Previous projects have provided valuable knowledge and experience in some of the technical challenges of the use of a Smart Grid, as detailed in Appendix 9. However, as will be described in Section 6, there are many gaps covered by SESG's innovative approach.

Some of the key objectives of smart grid applications are:

- Utilisation of the existing network capability and enhance network capability through automated actions;
- Providing TSO and DNO effective interface to facilitate the use of resources and ensuring security of the whole system;
- Employing advanced monitoring and control systems to enable the operator to have control on power flow and how the network behaves in real time.

<u>A smart grid application ensures the right balance between operational complexity and asset investment</u>

The SESG provides the following benefits which are discussed later on in more detail:

- Enhancing the network capability and avoiding constraint cost;
- Increasing network resilience; and
- Creating a platform to use distribution network resources.

3.3.1 Enhancing network capability

The methods demonstrated in the SESG project will provide the extra transmission capability the network requires to accommodate the increasing level of European interconnection and renewables by removing the transmission constraints. These constraints include:

- Steady state voltage (managing high voltage conditions)
- Dynamic voltage stability
- Commutation of HVDCs
- Thermal overloading
- Rotor angle Stability

These topics, their consequence and financial cost to manage these issue, and how much savings which is envisaged by implementation of SESG is shown in Table 3-1. Further details on the calculation of this table can be found in Appendix 6.

Network Characteristic	How affected in the South East region	Consequence	Impact on Cost	How SESG Helps
Steady state Voltage	Low demand (when interconnectors are floating), long transmission lines (high charging gain)	Significant constraint cost to control voltage	In excess of **£14m** just in 2013 and will inevitably rise	No longer requires constraining generators => **£6m** savings per annum
Dynamic Voltage Stability	Long transmission lines, absence of voltage control plants (power station, FACTS) particularly at high transfer periods of interconnectors	With increasing the level of interconnectors the problem is exacerbated – Need for extra reactive power compensation	At least **£60m** extra investment once new interconnectors are connected (based on £20m unit cost for a 200MVar Statcom x3)	At least **£20m** savings by removing the need case at least one unit
Commutation of CSC-HVDC	Reduction in network strength (short circuit level) when large power stations are not running	Constraining the HVDC Interconnectors flow (**import capability**) and risk to **Security of Supply –** as a result of permanent shut down of the link	In excess of **£80m per annum** based on just 6% of time, and import restriction of 1000MW (500 MW on each bipole)	Allow unrestricted flow by providing a coordinated response (small disturbances will have less impact on commutation) – The savings are at least for half of that time (between **£35m-£45m per annum**)
Thermal overloading and Rotor Angle Stability	Following a transmission fault the loading level on the remaining circuits will be high and significant phase shift increase	Requirement for building a new transmission line	**circa £500m**	Defers/delays the need case

Table 3-1 Summary of network constraints mitigated by SESG and respective financial saving

3.3.2 Increasing network resilience

The SESG method provides greater visibility on how the network behaves and is able to estimate the consequences of potential faults. The state estimator tool can inform the system operator if at any point a fault could lead to a more serious incident (i.e. cascading fault). This will maximise the network resilience and benefits:

- GB Consumers who will not be at risk of blackouts due to large disturbances on the transmission level (i.e. avoiding a scenario similar to London Blackout in August 2003 resulting in severe interruptions in the capital). This area of the network in winter peak conditions has always been a major energy gateway to provide security of supply through power import on interconnectors. In the future with increasing the number of interconnectors, the resilience of the network becomes even more important given the reduction in generation margin (available at GB) and dependency of the secure energy supply to have the ability to trade power across interconnectors.

- Transmission and distribution network users (i.e. Generators). This area of the network accommodates a nuclear power station, number of windfarms and solar PV farms, and HVDC interconnectors. The resilience of the network will improve which in turn reduces the risk of being disconnected due to network disturbances. The small disturbances on the transmission networks can be detected in real time and mitigating measures will be applied to avoid damaging the plants, or any disruptions in their operation.

3.3.3 Creating a platform to use distributed resources

Various resources such as demand side response, energy storage, and embedded generators within the distribution network, if aggregated (i.e. their collective effect), can be used to manage both transmission and distribution technical challenges with regard to providing capacity. There are however technical and commercial challenges which need to be addressed in order to create a platform to ensure use of this ever increasing capability. The SESG project aims to demonstrate (both technically and commercially), by use of a combination of wide area monitoring and control (WAMC), and commercial innovation, the use of distributed resources can be feasible.

Electricity Network Innovation Competition Full Submission Pro-forma

Section 4: Evaluation Criteria

This section should be between 8 and10 pages.

The SESG project will support a low carbon future by enabling the unconstrained operation of interconnectors through an innovative method of managing the system.

a) Accelerates the development of a low carbon energy sector and/or delivers environmental benefits whilst having the potential to deliver net financial benefits to future and/or existing Customers

The Department of Energy and Climate Change (DECC) set out the target of achieving emission reduction to 67% of 1990 levels by 2020 and 50% by 2027. SESG will play an important role in enabling the UK to meet its low carbon emission targets by enhancing network capability to accommodate the low carbon generation technologies in the south east.

Replacing fossil fuel power plants with renewable sources of generation is a decisive factor in the development of low carbon energy policies. In DECC's "Carbon Plan", more European Interconnection was identified as a key element to achieve these targets and the ideal location for interconnection with Europe is the South East. However, this area is a heavily congested area which will exacerbate with the introduction of new interconnectors (NEMO Link and Eleclink) as well as the extra renewable generation. The SESG project provides an innovative, quicker, cheaper, and environmentally friendly option to increase the network capability. The SESG facilitates the connections of low carbon technologies such as Solar PV and Wind, as well as unconstrained powerflow across the European interconnectors:

- The potential CO_2 savings which can be achieved from smooth connection of Wind and Solar alone in this area is shown below (assuming a 30% load factor for wind, and 10% for solar PV) is in excess of 3 million tonnes of CO_2 per year based on expected 2020 installation level (based on CO_2/kWh of 0.48kg/kWh)
- The 2GW European interconnection in the south East will result in further savings in excess of 6 million tonnes of CO_2 per annum.

It must be noted that the savings here presented are for the generation of renewable energy which SESG enables to connect in a timely manner. The achievement of such potentially high levels of saving on carbon emissions will be facilitated by enhancing the transmission and distribution network capability in the south east region by the SESG. In section 3, the conventional transmission reinforcement options were discussed. The solutions such as transmission lines, large substation plants (i.e. SVC, STATCOM) all have environmental impacts during the installation, commissioning, and the lifetime of their asset.

For instance, in case of the overhead line required in the South East, quantification of the exact environmental impacts associated with it is difficult since it is largely dependent on location factors such as "disruption to community" etc. However, the following environmental issues are common when building new transmission infrastructures which by the SESG will be avoided:

- Land use;
- Noise;

- Public health and safety;
- Sensitive plants and animals;
- Soil erosion;
- Visual impact.

The carbon savings, and energy savings associated with the SESG are detailed in Appendix 1. The financial benefits are described in Section 3, and supported by the Cost-Benefit Analysis in Appendix 6.

b) Provides value for money to electricity transmission customers

The SESG project by developing alternative, and smart tools (both technical and commercial), provides more economic, efficient, and easy to implement means of network design and operation.

- National Grid as the transmission owner in England and Wales, will use the SESG to facilitate customer connections in a timely manner at an optimum cost thanks to the advanced network knowledge available through enhanced monitoring as well as the coordination between transmission and distribution. These two factors will help better understand the assessments for new connections to the transmission grid, enabling the use of resources that were never available to the system operator and avoiding the time delay (as well as financial) of the additional capital investment under business as usual.
- The application of the tools developed by SESG, is envisaged to be used in other parts of the network which face similar challenges such as:
    - South West of England (with increasing the penetration of embedded generation, and large infeeds such as the new nuclear power station);
    - North Wales (due to connection of offshore windfarms);
    - North East (due to connection of large offshore windfarms);
- The GBSO will benefit from SESG by diversifying the tools available for more economic and efficient operation of the grid, as well as creating additional tools to enhance system resilience;
- The SESG increases the network resilience, by allowing the operator to access a wider range of actions through improved state estimation. This will benefit the customers in the sense that transmission network users (DNOs, Generators, Interconnectors, etc.) will not face the plant damage due to unexpected transmission faults. Further detail on how SESG operates is discussed in Appendix 5.2.

As described in section 3 (Business Case), the SESG will have some inherent benefits which are not dependent on deployment of low carbon technologies. This has been calculated in our CBA to be in the region of <u>£6m per annum</u> (just for the South East Network). With the expected increase in the volume of low carbon technologies such as solar PV and wind, and European Interconnections, this project will provide savings up to <u>£500m per annum</u> for the

GB consumers.

Identification and Selection process for Project Partners

National Grid sought project proposals for South East Smart Grid with a view to submitting a developed project to the NIC. The process which National Grid went through began in September 2013, when the priorities for innovation on design and operation of the transmission system was identified and subsequently published as part of Electricity Ten Year Statement (ETYS) in November 2013. We began the stakeholder engagement to gather ideas from our stakeholders, understand the solutions they can offer, and then sought agreement across the business on 2014 Network Innovation Competition projects. We formally invited various stakeholders to submit their expression of interest, their proposals on the solutions they can offer, and level of engagement for the SESG project. The publicly available SESG briefing note entailed broad issues that National Grid wish to address and whether interested candidates are able to develop a project to the timeline required by the NIC.

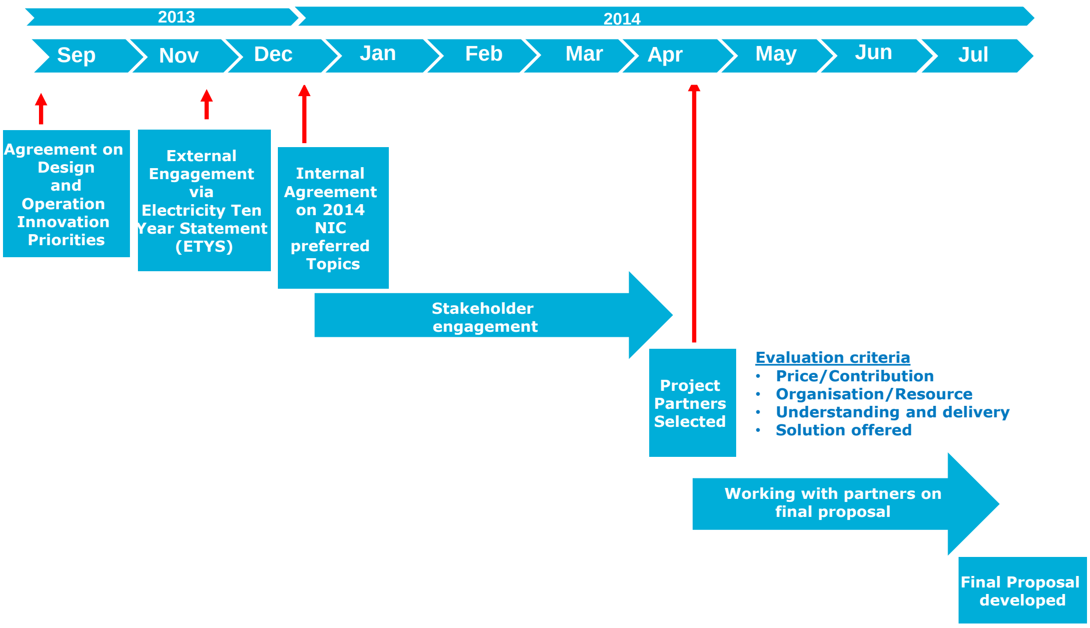


Figure 4-1 Partner Selection and Development of SESG Timeline.

Expression of interest alongside with qualifying information (proposals for solution description, relevant experience, project budget proposals, indication of external funding/contribution, compliance with NIC terms and conditions-Intellectual Property Rights etc.) were requested from all interested candidates within a specified time frame. National Grid's innovation team, procurement team, and the SMARTer System Performance Manager oversaw the process, and the selection criteria which were based on:

- Price/Contribution
- Organisation/resource

- Understanding and delivery
- Solution offered

Rationale for Partner selection

Selection of project partners was an important decision to make and a number of factors were considered around risk, capability, experience, contribution level as well as meeting the NIC governance criteria to qualify as a project partner. The partners that SESG envisaged for this project will bring extensive experience to this project which creates more value for the consumers and reduces the risk. The following partners were selected as part of this process:

- Siemens, as the technical solution provider.
- Imperial College of London leading the academic support and knowledge dissemination.
- Elexon leading on commercial support.
- UKPN, as the DNO of the South East, to ensure a collaborative and joint up approach in coordinating the resources.

Siemens, Elexon, and Imperial College were selected amongst a pool of different competitors in the technology provider, commercial and academic sectors, respectively. Given that UKPN was the only possible provider for the particular role required in this project, there was no competition in the selection process. UKPN is the DNO for the South East of England and therefore it was the only appropriate DNO that could be selected for this project because of the need to model their network and control resources on their system.

SIEMENS

Siemens have been identified and selected as the project partner (technology provider) for the SESG for the following reasons:

Siemens has extensive experience of LCNF (Tier 2) bid process, having worked as a project partner to various DNOs in each of first 4 years of the programme and participated in Expert Panel and Consultant Sessions, with 100% success record.

Siemens has proven delivery capability around large scale system integration and innovation projects; this includes its role as overall control architecture supply and integration for the largest smart grid project in the UK today, the Ofgem funded Customer Led Network Revolution.

Siemens is a technology and solution provider to National Grid and has delivered a broad range of type registered and innovative control solutions, such as Operational Tripping Systems. Siemens has also provided innovative ancillary services like active Frequency management (Fast/Slow response), active reactive power management and active load management to National Grid as part of the CLASS project delivered to one of the UK DNO.

Siemens's nature and level of contribution compared to other interested parties was higher and more beneficial for SESG.

Imperial College London

The Imperial College of London's control and power department has world class reputation in research and development in the subject area proposed for SESG. The group provides the capability to perform number of laboratory testing and simulation for the applications proposed for this project. The group has also been active in previous IFI/NIA/LCNF projects. The previous IFI funded project focusing on the tools and techniques (feasibility studies) is the key project which has been completed successfully by this institute, and it allowed us to develop SESG project to demonstrate the tools and techniques which were identified as feasible for trial.

ELEXON

ELEXON has been selected as partner because of experience of running the balancing and settlement market. We envisage the ELEXON's role as advisor alongside the academic partner being vital for development of the commercial innovation aspects of the SESG (market arrangements, developing products, impact assessment).

UK Power Networks

UK Power Networks (UKPN) is the local Distribution Network Operator (DNO) for the south east of England. It is expected that significant volumes of embedded generation to be connected in this area which in turn requires transmission and distribution reinforcements. By working closely with UKPN, ensuring the transmission and distribution related issues are considered in parallel, as well as facilitating the access to the sites where monitoring devices need installation.

c) Generates knowledge that can be shared amongst all relevant Network Licensees

SESG generates a number of key areas of knowledge which can be shared amongst all relevant Network Licensees:

- Design of new smart and effective system monitoring tools. This includes new system monitoring devices in addition to the improvement of existing equipment;
- Validation of Smart Grid network under different system conditions. The different Smart Grid parameters are tested for specific distributed and transmission resources hence can be used for other Smart Grid applications;
- The coordination of equipment located in different voltage levels (Transmission and

Distribution). The efficient method of communicating with distributed resources is explored;

- The optimal operational arrangement of DC links connecting to the onshore transmission system is determined. This knowledge can be handed over to the other Transmission Licensees for any offshore connection to the main transmission system.

The description of the approach to knowledge dissemination, is detailed in Section 5 of this document.

d) Is innovative (i.e. not business as usual) and has an unproven business case where the innovation risk warrants a limited Development or Demonstration Project to demonstrate its effectiveness

Previous smart grid projects have mainly applied to small scale and specific applications. For example as described in Appendix 9, we have investigated the use of monitoring and control at the transmission level for managing some of the transmission constraints. Project VISOR (of which NGET is a partner) is developing advanced monitoring of the network to manage wide range of system related issues (such as sub-synchronous oscillations, inter-area oscillations). Number of projects led by DNOs under Low Carbon Network Fund (LCNF), have investigated the use of DSR, and storage to manage localised constraints.

In particular, the main differences between SESG and project VISOR must be noted. Whilst the SESG project intends to fully take advantage of National Grid's active support and partnership with Scottish Power on the VISOR project, SESG's purpose of monitoring go far beyond the Sub-Synchronous Oscillation (SSO) monitoring which VISOR focuses on. Using this monitoring, SESG aims to provide a control scheme that will use all available distributed resources (i.e. demand side response and distributed generation) in the most appropriate manner.

<u>We believe distributed resources have the potential to help with managing transmission constraints and provide significant benefits to the consumers.</u> To enable this potential, whole system monitoring and control, resource estimation, and initiation, as well as new commercial measures are required. This application at such scale has not been demonstrated before, and given the potential, we have identified it as an area for immediate innovation.

SESG utilises all available resources connected to the distribution and transmission system for the first time, at such large scale. The South East is a very complex network; therefore, the modification of existing operating arrangements requires considerable investigation and effort. There are different parties at different voltage levels engaged in the project. This adds to the complexity of the project. <u>The concept proposed in SESG, cannot proceed as be business as usual due to the following risks:</u>

Technical Risks

- System Monitoring –The monitoring and control system are extended to different distributed and transmission resources. Conventionally, the monitoring devices have been assigned for specific applications. SESG develops comprehensive system monitoring involving devices attached into different voltage levels with different specifications.

- Coordination of Distributed and Transmission Resources –The coordinated response of distributed and transmission resources will be tested and validated in SESG. For the first time all available resources will be used to mitigate a system or network issue.

- Distributed Response Identification –Qualifying and quantifying the response from distributed resources are challenging processes. Doing this requires the involvement of different partners and is not a common practice. A range of distribution resources, including generation, compensation equipment and demand, shall be tested under different network/system conditions.

Operational risks

- Management of Distribution and Transmission systems - The real-time management of Distribution and Transmission networks is a complex procedure require specific tools and control schemes

- Failure of main system monitoring - Building a backup /support centre when the main monitoring system fails is essential. It requires detailed investigation of the network and investment if necessary

Commercial risks

- New response market requirement – The existing market arrangement is not able to accommodate response from the various Smart Grid devices. A new market regime is required to incorporate coordinated response from transmission and distributed resources.

Regulatory risks

- The existing business standards such as The National Electricity Transmission System Security and Quality of Supply Standards (NETS SQSS), Grid Code, and Distribution Codes may not be aligned with future network development project such as SESG. Whilst there are well defined processes around required modifications to these codes and standards, the knowledge and evidence for such changes can only be obtained via demonstration projects such as SESG.

The SESG will create significant learning in how future Smart Grids can interact to provide maximum value for the consumers. The coordinated TSO/DSO actions and interactions are all new to GB, whilst there is significant potential in creating a framework for roll out of such concept in a very near future. The learning generated by SESG will significantly enhance the knowledge gained from project VISOR or other LCNF/NIA/IFI projects.

(e) Involvement of other partners and external funding

National Grid engaged with external stakeholders once the NIC 2014 project was identified. A briefing note indicating SESG candidates was available on the company's website. There have been discussions with relevant customers, suppliers and partners to elaborate the project's aim and objectives in further detail. A considerable number of candidates, ranging from technology providers, the south eastern network licence area, UKPN to demand side aggregator and universities, have shown interest in SESG.

NGET has discussed the need for external funding, and all of our partners are contributing (both in-kind, and financially) to this project. The external funding made available to this project is mentioned in Section 1, and detailed in Appendix 2. The details of our partners can be found in Appendix 7. In addition, their letters of support are included in Appendix 8.

Imperial College of London

Imperial College of London is the academic partner of the project, and provides academic expertise, as well as data evaluation, validation, quality control, testing, and knowledge dissemination.

Siemens

Siemens was among the candidates that expressed interest in the SESG project and it submitted a Technical Proposal as part of the Initial Screening Process (ISP) stage. Siemens was selected as a partner to the project using key evaluation criteria like contribution level, relevant experience and capability.

Siemens will be the key technology provider with a substantial involvement (technology development) to deliver WP1B (State Estimation), support National Grid and UKPN in 1C (Response Evaluation) of the project, as well as being involved in other stages.

Siemens has allocated resources to support the SESG project and has confirmed availability to support full bid submission and subsequent assistance as part of future Expert/Consultant Panels. This support would be provided by Siemens as part of its 'in-kind' contribution as role of partner.

UK Power Networks (UKPN)

UKPN recognises the importance of the project and have agreed to partner with us and contribute to the project. The technical description of the project was shared, discussed and agreed in a number of bilateral discussions with UKPN. UKPN as a project partner allow the development of the state estimator on transmission and distribution system, allowing the access to the distributed resources within the DNO's network.

The role of UKPN and their scope of works is made up of the following aspects of SESG delivery:

1) Dynamic system model - data provision and model validation;

2) PMU installation - site selection, connection design, site access, commissioning and trial;

3) Contribution to overall project management - provision of expert knowledge and experience of the distribution network and distributed resources, and the associated challenges and opportunities.

Elexon

Given the nature of trials proposed as part of the SESG, and need for development of commercial services to enable the roll out of the concept to other parts of the network, Elexon will provide expertise in designing new commercial services. Elexon in conjunction with our academic partner support the immediate roll out of the SESG to other parts of the network, and help in developing the non-build solutions.

(f) Relevance and timing

Interconnection with Europe is a major operational and environmental challenge facing the UK over the next two decades. The South East in particular has the operational challenge of being a very congested area and has had several system incidents in the past two years. There will be two interconnectors connecting in this area in the near future: Nemo Link and Eleclink.

National Grid will need to better understand the specific dynamics of the area in order to determine the most cost effective option of reinforcement. Future reinforcements will include a large amount of static and dynamic compensation in order to ensure sufficient reactive support but there is a requirement to understand how quickly these pieces of equipment would need to respond to a system event. Also, there is the need for synchronising the control of all the devices in the area. The SESG project will provide a Wide Area Monitoring System (WAMS) that allows this to be accomplished.

In addition to interconnection, under severe network conditions (for example, high demand, low demand, and high wind high solar production) the operator may need constrain the output of renewables to manage the network. SESG ensures smooth operation of renewables under severe network conditions.

Electricity Network Innovation Competition Full Submission Pro-forma

Section 5: Knowledge dissemination

This section should be between 3 and5 pages.

☐ Please cross the box if the Network Licensee does not intend to conform to the default IPR requirements.

The SESG project will develop invaluable learning for other network licensees as well as for the electricity industry in general. Knowledge will be disseminated continuously throughout the duration of the project.

The SESG project will be the first of its kind to demonstrate the effectiveness of a whole system approach in providing the capability the network requires. The concept will be extended across the system (as a non-build solution) and therefore knowledge dissemination will be an important part of this project. The knowledge dissemination will have some specific objectives:

- To introduce the concept of a whole system transmission and distribution planning, and build confidence amongst the stakeholders with regard to operability of the concept; and
- To send market signals to develop the tools and solutions in large scale and help in commercialisation and roll out of the concept to other parts of the network.

To achieve the objectives above, it will be required to create the necessary forums to share the learning as part of SESG with various stakeholders; ranging from members of the public in the South East region, to technology providers, and DNOs. This section will describe the approach SESG project will take in knowledge dissemination.

5.1 Knowledge dissemination

The successful implementation of SESG, and roll-out of the concept across the system requires a systematic knowledge sharing at all stages of the project. SESG will share the knowledge of project equitably amongst all stakeholder groups as identified in Figure 5-1.

Figure 5-1 Knowledge Dissemination Audience.

Knowledge dissemination continued

5.1.1 Development phase

During the development phase of the SESG's state estimator, various elements and areas will generate new knowledge which will be disseminated:

- **SESG State Estimator (a Whole System Approach):** The development of control systems monitoring the system parameters (i.e. voltage, phase angle etc.) and identify system integrity limit for the south coast under normal, and various contingencies. The state estimator will consider both transmission and distribution network's behaviour ensuring a fully optimised control system for the SESG. The target audience of this work include <u>TOs, DNOs, technology providers and academia</u>.

- **Resource Estimation:** The SESG will develop an innovative tool which enables estimation of required response from distributed resources to manage the identified constraints on the transmission network. Such resources are embedded within the DNO's network and communication capability, availability of such resources, and impact estimation are the learnings which will be disseminated. The target audience at this stage are <u>TOs, DNOs, technology providers, academia, demand side aggregators, and embedded generators</u>.

- **Commercial optimisation:** The optimisation in the use of transmission and distribution resources and development of commercial services to enhance the network capability (as appose to capital investment) are some of the important areas which SESG's knowledge dissemination will expedite the roll-out of the concept. The target audience are <u>TOs, DNOs, academia, generator companies, and interconnectors</u>.

- **Innovative Network Development:** SESG will help in building confidence amongst the consumers with regard to innovative measure taken to develop a safe, sustainable and economic electricity network. The SESG creates the opportunity for the <u>local communities</u> to be more engaged with the electricity sector by:
  - Developing the understanding of the complex measures taken by the network companies to be more economic and efficient through innovation;
  - Understanding of the value which the SESG bring for them (i.e. savings on electricity bill, and less environmental impact);
  - Encouraging more involvement of younger population in development of future networks by showcasing innovative and exciting projects such as SESG and creating a new image of what the 21st century electricity industry looks like.

5.1.2 Post-project completion

The SESG's developed tool:

- **Constraint management:** The ability to dynamically evaluate the state of the system in the South East, and avoid unnecessary constraints in real time.

- **Real time data access:** It is envisaged the future grid development activities (i.e.

Knowledge dissemination continued

generation and demand connection), and research projects require greater access to data and in such a way to allow comparing system behaviour between different parts. The SESG tool will provide access to such data on the network which enable more economic and efficient transmission and distribution planning in the south east, as well as more effective research and developments in this area.

- **Smart Grid Training Centre:** The system operator, transmission and distribution planners, OFTOs, and academic institutes will have the opportunity in the future to be trained on smart grid platforms developed for SESG. The training centre based at Warwick in collaboration with Transmission National Control Centre (TNCC) using the new developed monitoring and control platform will be a vital centre for developing the capability within the industry in such areas.

5.1.3 Knowledge dissemination approach

The SESG project has a range of stakeholder groups which inevitably have differing levels of expertise and interests. The knowledge dissemination methods envisaged for SESG ensures the stakeholders receive the required knowledge that are relevant to their own business and needs via targeted dissemination activities. National Grid's customer and stakeholder engagement team will oversee the methods to ensure a clear, targeted approach in knowledge dissemination and receive feedback from our stakeholders at various stages.

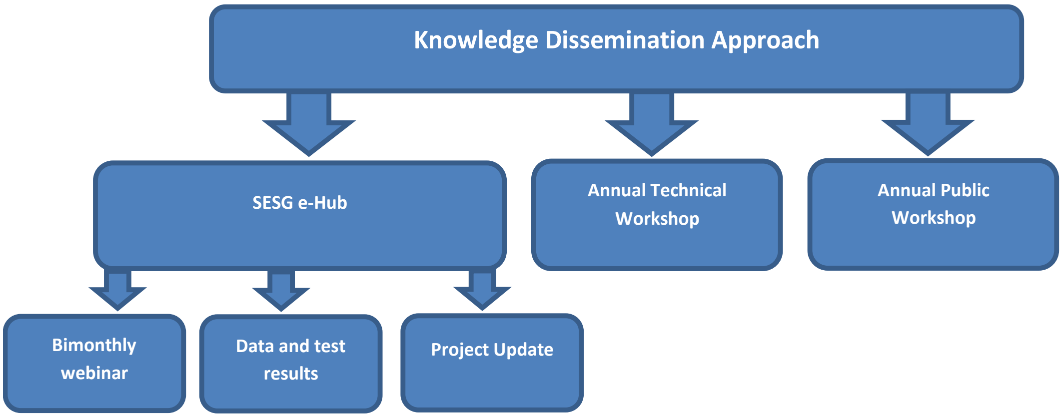


Figure 5-2 Knowledge Dissemination Approach

The **academic partners will assist significantly** in the knowledge dissemination. A project e-hub will be created in order to provide regular update to the stakeholders, share the available knowledge and data, and announces the significant learnings at different stages of the project. We will be hosting bi-monthly webinars inviting the key partners to present the developments and demonstrations carried out to the stakeholders. We will also hold physical knowledge sharing sessions with presence of key stakeholders of the project.

We believe the transformation of grid into a SMARTer grid, benefits from more consumers' support. We therefore propose to hold annual knowledge sharing event for the member of the public geographically reside in the areas we are developing this innovative solutions. This is to show the benefits, savings, and future opportunities which will be created as part of this project to the end-use electricity consumers. The public workshop proposed for SESG will have two purposes:

1. To share SESG's vision, and how network companies, technology providers, and service providers are joined up with one goal; "to be more economic and efficient" and how SESG directly benefits them;
2. Listening to consumers, to those who are directly benefiting from SESG (i.e. residents of the areas who were going to be invited into a public consultation on building a transmission route under a business as usual), and understand what they would like to see from future smart grid projects.

National Grid has extensive experience from previous stakeholder and customer workshops. The feedback received from these so far shows greater interest from the end-users to be engaged in the decisions, projects, and what we do and how they affect them. In addition, we have created forums such as the "connecting blog" where we update the general public on a range of project and topics that National Grid is involved in. We are also active in supporting STEM subjects and work closely with schools to give a better flavour of what engineering is all about. All these are examples of how we routinely engage with our stakeholders and the experience gained will ensure a successful dissemination of all the knowledge generated by SESG.

5.2 IPR

It is not anticipated that SESG will fall outside the default Intellectual Property Rights (IPR) arrangements defined by NIC governance document. In addition to the steps described above in knowledge dissemination, this section will make specific reference to the work carried out to ensure full compliance with default IPR. A full review of the section 9 of the NIC governance document has been carried out with SESG partners, and as well as the agreement on the learnings of each work package (as described in section 2). The following steps will be taken to ensure a full compliance with default IPR:

- National Grid has detailed the expected learnings of each work package. This has been agreed with the partners and all relevant data, models, simulation results, and control system developed as part of SESG will be publicly available on SESG e-hub

- It is expected that the technology provider of the project may wish to contribute to development of some of the Solutions (control hardware and software development, and monitoring hardware) in order to retain the IPR. This will fall under "Foreground IPR" as described in section 9 of the NIC governance document. Any product developed on such basis, will be made available for purchase on fair and reasonable terms. In the collaboration agreement between National Grid and the partners the "Foreground IPR" will be specifically described to ensure the compliance with section 9 of the NIC governance document.

Electricity Network Innovation Competition Full Submission Pro-forma

Section 6: Project Readiness

This section should be between 5 and 8 pages.

Requested level of protection require against cost over-runs (%): 5
Requested level of protection against Direct Benefits that they wish to apply for (%): 50

The SESG project has done all work necessary and is on the road to success.

6.1 Background

The success of the South East Smart Grid (SESG) project is dependent on several factors outlined in Figure 6-1. All of these factors have been considered and we are confident that all these areas have received sufficient level of attention for the project to commence without delay:

- **Previous Projects:** We have identified a number of projects related to SESG which have provided valuable learning points to both National Grid and our partners.
- **Technology readiness**: Our partner Siemens has had previous experience with the solution platform "Spectrum Power" and we are confident that the platform will provide the most appropriate solution for SESG.
- **Project Governance:** A strong governance framework has been put in place to ensure the success of the project.
- **Quality Control:** Steps have been taken to ensure accuracy of all information.
- **Inherent Benefits:** The project will deliver valuable knowledge irrespective of the success of the low carbon benefit.
- **Contingency Planning:** Risk assessments are in place to ensure any risks have a sufficient level of mitigation.

Figure 6-1 Factors in the success of SESG. .

Project Readiness continued

6.2 Previous Experience

We have identified several related projects which will provide learning to the delivery of SESG. The learning points from these projects are outlined in Table 6-1 and further detail can be found in Appendix 9.

Project	**Learning Points for SESG**
National Grid Humber SmartZone	✓ Installing Phasor Measurement Units ✓ Installing Random Access Memory Units ✓ Upgrading Communication Systems ✓ Intelligent operational inter-trip scheme ✓ Overhead lines dynamic thermal rating ✓ Congestion Management ✓ Alarm and protection setting optimisation
ENW Customer Led Ancillary Services Support (CLASS)	✓ Local distribution control scheme ✓ Frequency Management ✓ Load Management ✓ Voltage Optimization ✓ Distribution Automation
Northern PowerGrid Grand Unified Scheme (GUS)	✓ Central and Local distribution control scheme ✓ Constraint Management ✓ Experience with Spectrum Power
Low Carbon London	✓ Decentralised energy trial which is investigating new Active Network Management (ANM) automation and control techniques. ✓ Demand response from industrial and commercial customers
Flexible Plug and Play	✓ New commercial arrangement allowing the DNO to manage the output of the distributed generator to ensure the network constraints. ✓ High-speed telecommunications platform for advanced control and monitoring. ✓ Trial smart technologies including active network management (ANM), automatic voltage control, dynamic line rating, novel protection scheme for reverse flows and RTUs interfaced with ANM
Project VISOR	✓ Wide Area Monitoring ✓ Detection of Sub-Synchronous Oscillation ✓ Detection of Inter-Area Oscillations
America OG&E's Smart Grid	✓ Advanced metering infrastructure ✓ Dynamic pricing programs
America Ruston Smart Grid	✓ Meter data management system (MDMS)

Table 6-1 Learning from other Projects related to SESG.

Project Readiness continued

In particular, SESG builds on the Humber SmartZone project, a project undertaken by National Grid which was funded through the Network Innovation Allowance (NIA). This project was developed as an alternative solution to reinforcement. The project involved the development of a proof of concept that provided flexible enhanced circuit ratings through a combination of wide area monitoring, predictive ratings and dynamic security analysis. Through this project, National Grid gained invaluable experience that will ensure the success of SESG. We have also carried out a detailed feasibility study with Imperial College of London, on the reliability evaluation of smart solutions which will be demonstrated as part of SESG.

However, SESG will still need to fill in the following gaps:

- Comprehensive system monitoring combining both Transmission and Distribution Level (whole-system approach)
- Enabling the use of distributed resources to manage transmission constraints (tackling communication, cyber security risks, etc.)
- Development of market signals to enable the roll out of the concept

These three points demonstrate the ground-breaking nature of SESG.

6.3 Technology Readiness

Our partner Siemens is the technology provider for the SESG project. Siemens has extensive experience in providing solutions to the energy industry. *Spectrum Power*, the solution platform suggested by Siemens to deliver the SESG project, has been previously used in many projects around the world. As shown in Figure 6-2, Siemens's tool is used by over 1600 control centres worldwide (Transmission & Distribution) with over 200 in the UK and Continental Europe. Amongst these control centres, 34 of them are Transmission Control Systems including ENTSO-E Belgium, BritNed UK, Dong Energy Denmark and TransnetBW GmbH Germany.

Typically a Spectrum Power Platform is deployed on a customer basis. Each individual customer will have their own geographical, asset and/or voltage boundaries often determined by the regulation within a particular market or country. Spectrum Power Platform has been previously deployed for transmission and distribution customers across a range of voltage levels.

There is no proposed modification or development considered for Siemens' Spectrum Power Platform. However, it must be noted that the co-ordination between transmission and distribution systems of the SESG is a new, untried application of this platform. The implementation of this platform will require separate consideration in a manner consistent with how these areas would be approached for any project.

Electricity Network Innovation Competition Full Submission Pro-forma

Project Readiness continued

Figure 6-2 Control Centres that use Siemens Spectrum Power

In particular, Siemens has used this platform in the project titled 'Northern PowerGrid Grand Unified Scheme (GUS)' shown in Table 6-1. This project was part of the Customer Led Network Revolution (CLNR) and a major component of this is the implementation of a Grand Unified Scheme (GUS) made up of a combination of existing and novel network devices. The aim of the GUS was to demonstrate increased network flexibility and capability by coordinated action (control and monitoring) of enhanced network devices. Siemens will be able to apply many of the learning points from this project to SESG.

From the GUS project and all the other projects existing worldwide, Siemens has gained extensive experience in using the *Spectrum Power* platform for the delivery of complex data systems to automatically manage the operation of power networks and they are confident that it can use it to develop an appropriate solution for the SESG project.

6.4 Project Governance

A project team will be formed to run the SESG project. The team will be led by National Grid and will provide regular feedback and updates to senior management. Dr. Vandad Hamidi will be acting as the key point of contact with Ofgem, project delivery team, and the steering committee. Appendix 7 provides more detail on the project team that will be formed to deliver the SESG project.

Project Readiness continued

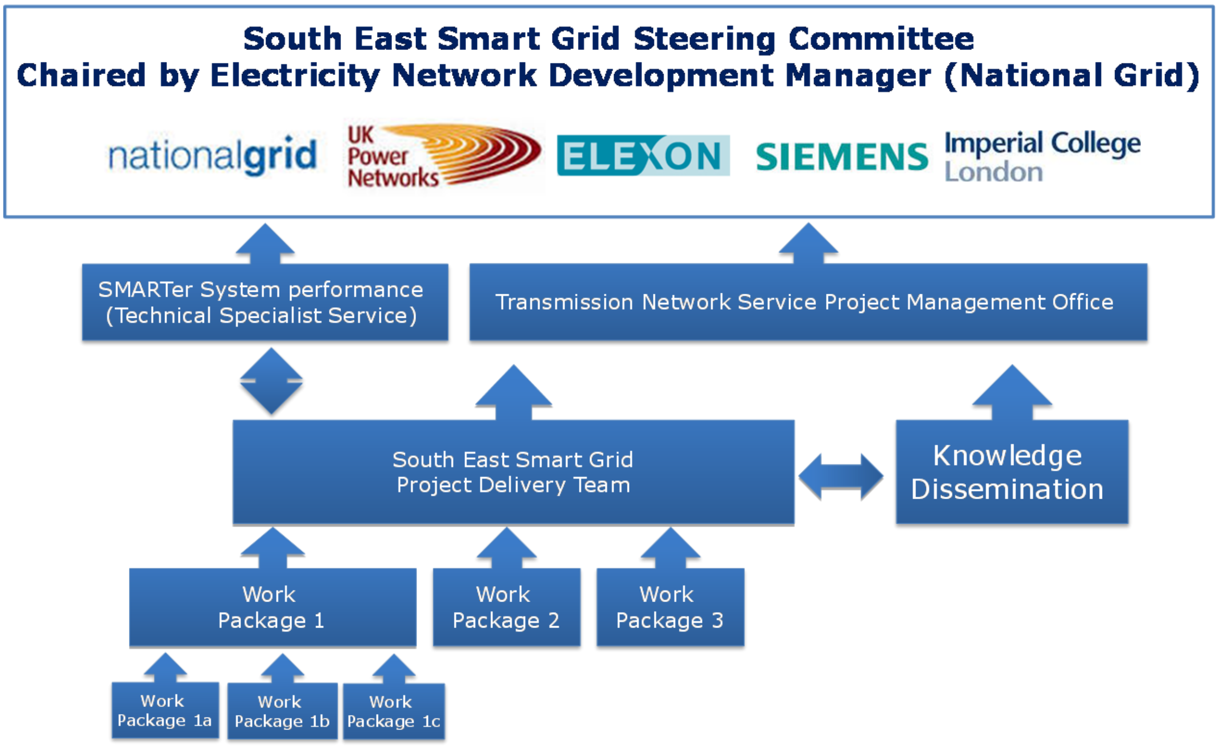


Figure 6-3 Project Management Structure

SESG will start in a timely manner. The partners have been engaged with SESG since initial stage of the project and have valuable experience about smart grid and south east network. They are fully aware of project milestones, their role and contribution (as detailed in Section 4e), and have confirmed that the project objectives are achievable. A series of work packages were agreed with the partners which fed into the development of a high level project plan shown in Appendix 3. A summary of the timings of this project plan is shown in Figure 6-4.

As well as the project plan, due to our partner selection, there would be no requirement to perform a tender process to find the supplier for the technology, thus ensuring no delay to commencement of the project. We are also confident that the solution platform provided by our partner Siemens (*Spectrum Power*) is fit for purpose and, due to their previous experience, we are confident that this technology would be deployed without delay.

In terms of the procurement of response from service providers, we have conducted a review of potential for procurement of the services which will be required for the purpose of trial in SESG. We are confident that the DSR aggregators that we are working with as part of our Balancing Services, or were involved in the call for proposal for NIC projects have access to sufficient volume of DSR within this area so the trials can take place. A competitive procurement process will then take place to ensure we procure this service at the best price, and from a range of service providers than only one single service provider.

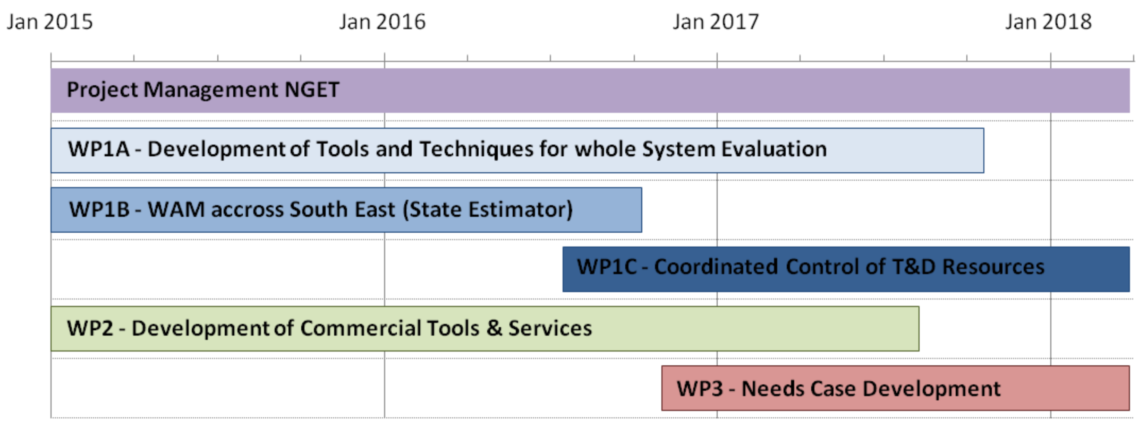


Figure 6-4 High Level Programme (See Appendix 3 for more detail)

We have taken a number of steps to accurately estimate the costs and benefits of the project. The project partners assisted NGET to estimate the cost and benefit of the SESG project. The detailed cost evaluation was used to build up the project costs and this is detailed in the full submission spreadsheet found in Appendix 2. Partners have a considerable stake in the project cost estimation and that similar projects have been assessed by NGET and key partners in the past. The list of these projects is provided in this section. Therefore SESG costs and benefits can be benchmarked considering the previous successful projects.

We will employ a number of measures to minimise the possibility of cost overruns or shortfalls in Direct Benefits. NGET detailed project plan and KPIs ensures the risks associated to SESG are being captured and handled. We have contingency plans in place to ensure any risks are appropriately mitigated. The risk register, and the contingency plans are set in a way to capture risks in different sections of the project.

6.5 Quality Control

We have verified all information included in the proposal. There is a procedure to verify information provided to SESG before implementation to ensure the quality of the data being used. A combination of past system events, and simulation exercise will be used for verification of the initial data used for the SESG. The data gathered as part of trials and demonstrations, will go through a separate validation exercise using post-event simulations which helps in validation of the proposed control system for SESG.

6.6 Inherent Benefits

SESG will deliver learning irrespective of the take up of low-carbon technologies and renewables. Irrespective of the delivery of the carbon benefits described in section 4, the learning points from this project will be invaluable for the efficient development of the transmission system. The learning from this project will allow to make better decisions on investment in the future and the knowledge gained from the transmission system will be used to determine the best option.

6.7 Contingency Planning

Processes are in place to identify circumstances which could affect successful delivery of the project. We are confident that given the significant volume of preliminary work carried out so far, combined with the experience of the project partners SESG is on the road to success.

However, as part of developing the proposal for SESG, we have engaged our partners in identifying the potential areas which require careful risk assessment, to as the success of the SESG project is dependent on managing the risks appropriately. We have identified these potential risks to the project and have put mitigation actions in place to ensure the success of the project. A full risk assessment is included in Appendix 4.

The project steering group with representations of all partners will oversee the project and an update on the project risks will be provided to the steering committee every month. The National Grid's Global Risk Management System (GRMS) which has been used to manage number of processes and project across National Grid, will be used for SESG. Given the innovative nature of the SESG project, there may be exceptional circumstances which the project will have to be suspended. The steering committee will be provided with a detailed report on the causes, and risks which has led to not being able to deliver the agreed tasks within SESG. The steering committee will then provide a detailed report, including the completed milestones, and what has not been delivered to the authority with proposed recommendations (i.e. delay the project, or suspension in line with NIC governance document sections 8.30-8.42).

Electricity Network Innovation Competition Full Submission Pro-forma

Section 7: Regulatory issues

This section should be between 1 and3 pages.

☐ Please cross the box if the Project may require any derogations, consents or changes to the regulatory arrangements.

It is not expected that the SESG project will require any derogations, consents or changes to the regulatory arrangements in order to implement the project.

7.1 Data Confidentiality

The data required for the SESG project is the data currently shared between National Grid, and UKPN under grid code (i.e. provision of data from DNOs as part of Week 24 data submission, and between National Grid and DNOs as part of Week 48 data submission), and as part of the trial of SESG, there is no requirement for any derogations or license exemptions.

The work package 2 (commercial service development) however will explore the potential areas where the share of the data such as the availability of demand side aggregators, under the existing regulatory regimes may not be possible, and therefore require modifications.

7.2 Balancing and Settlement Code

As part of work package 2, the services developed will be assessed in conjunction with existing services (i.e. Balancing Services, Short Term Operating Service) to ensure any areas which may conflict with the existing arrangements are identified and modification of the service, or the codes will be proposed.

7.3 The future of Smart Grid

This project is intended by attention to the Work Package 2 to contribute to providing clear commercial and regulatory frameworks towards the foundations of a future where Smart Grids become the business as usual for any network licensee. Both National Grid and our partner UKPN are highly active within Electricity Networks Association work streams, including the recent consultation surrounding Demand Side Response, and Smart Grid Forum work streams, and would consider that the practical understanding developed under SESG will inform technical, commercial and regulatory developments across that agenda.

Our partners will work together in Work Package 2 to identify the new market structures that may be required as part of Smart Grid deployment. WP2 focuses on the type of commercial services and new market arrangements which will enable this concept to be used in other areas of the network while taking into account the potential regulatory impacts of the innovative concept.

Electricity Network Innovation Competition Full Submission Pro-forma

Section 8: Customer impacts

This section should be between 2 and 4 pages.

8.1 Impact on Transmission Network Customers

The existing transmission network users in the area where SESG will be implemented include:

- IFA Interconnector (2GW Cross Channel HVDC Link)
- Dungeness Nuclear Power Station
- UKPN at grid supply points

And in the future:

- Eleclink (Cross Channel HVDC Link)
- Nemo Link (Cross Channel HVDC Link)

The implementation of the SESG does not require interruption of generation or supply capability of the existing or future transmission network customers. Therefore, it is not expected that the SESG project will have any adverse impact on the transmission network customers.

8.2 Impact on Distribution Network Customers

The SESG will be coordinating the response from transmission and distribution resources. In the work package 1b and work package 1c the monitoring devices necessary at the distribution level will also be implemented without any adverse effect such as interruption of supply, or quality of supply issues for the distribution network customers. We expect to recruit number of service providers within the distribution network which can respond to network constraints and this will be done via performing invitation to tender to prospective service providers with full coordination with UKPN.

8.3 Benefits to Transmission and Distribution Network Customers

The existing and future customers within the South East network (at both transmission and distribution level) will benefit significantly from the SESG platform, and the data and knowledge shared amongst them. The SESG will demonstrate an innovative and whole system approach, involving coordinated Transmission and Distribution Network operation to provide benefit for the consumers. This benefit results from the innovation experience that the SESG system platform provides, allowing National Grid to accommodate enhanced levels of interconnector access and further optimised transmission investment in the area. Knowledge dissemination throughout the project will ensure that all customers and other stakeholders have access to the knowledge produced by the project, which will support its replication and extension across the wider GB system.

The SESG provides greater resilience by implementing an enhanced monitoring of the transmission and distribution network. Such increase in resilience, will benefit the customers such as the nuclear generator (Dungeness Power Station) in this area, by being an additional measure for ensuring the long term safety of a nuclear site.

Customer impacts continued

With regard to HVDC interconnectors, the enhanced monitoring of the network provided by SESG, in addition to the resilience, will help in reducing the design and upgrade cost of these network users by providing more accurate data regarding network behaviour. Given the expected start/completion date of this project, the new interconnectors expected to connect to the network will have the opportunity to use the data from SESG platform to optimise their designs.

At the grid interface points between National Grid and UKPN, the coordinated monitoring and state estimation allow both NGET, and UKPN to consider a range of network issues in a much more coordinated way. Topics such as outage coordination, change in network characteristics and managing challenges such as high volts, etc. in long term can all be managed and any solution proposed will be based on the new capabilities provided by SESG.

Similar to transmission connected customers, the distribution network customers such as generators will see greater network resilience. The key benefit of SESG for them is enabling the distribution connected customers to provide new services to the grid.

8.4 Benefits to TOs, DNOs and connected parties

Designing and delivering the connection routes for new customers and undertaking wider network upgrades for system operation and asset related issues is part of the TO role, therefore two of the main benefits from SESG are offsetting the need for a new transmission route and the need for a new reactive compensation. Avoiding the TOs need to invest in infrastructure results in a direct benefit for the consumer. Other TOs would benefit from the learning on how these benefits can be achieved and replicated on other parts of the network.

Similarly, the DNOs will be able to offset a part of their new asset requirements associated with new connections at the distribution level, voltage management and other requirements (for example, those associated with the potential new European Demand Connection Code).

The DNOs will benefit from increased visibility of the networks provided as part of SESG as this will allow the optimisation of the power flows across the distribution and transmission systems and an optimised dispatch of the services and optimised overall distribution and transmission system operation.

The connected parties will benefit by the ability to be connected at an earlier date, and greater access as well as potential new market opportunities.

Section 9: Successful Delivery Reward Criteria

This section should be between 2 and5 pages.

Criteria 9.1

Completion of upfront partner engagement and high level collaboration exercises to enable technical and commercial design commencement

In order to achieve the project objectives of WP1A, WP1B and WP1C in conjunction, it is crucial that partner workshops are complete and specifications outlined to develop scope for whole system design.

Evidence

- Partner workshops run – May 2015
- High level technical/system architecture specification complete - July 2015
- Commercial framework specification complete – July 2015

Criteria 9.2

Monitoring and Control assessments complete and Whole System Evaluation Models developed

One of the key deliverables of the project is to enhance system state monitoring and estimation when transmission and distribution network topological changes. It is important that validated models are developed to allow the assessment of benefits of whole system estate estimation. Such validations must be carried our as per technical description of the proposed programme of works for Imperial College of London set out in Appendix 5.

Evidence

The following components should be delivered for success at this stage:

- Reports of partner assessments for Grid Supply Point capabilities and optimal monitoring locations complete for September 2015.
- Development of validated models enabling real time testing. The model developed must allow the simulation of WP1b components (at transmission and distribution level) by end of September 2015.
- Validation of models with control platform through computer simulation complete by February 2016.
- Development of Virtual Power Plant concepts to enable flexible resources in distribution networks to be trialled at WP1c by August 2016.
- Report detailing the description of real-time controller as implemented in a rapid control prototyping (RCP) platform from Opal-RT by the end of October 2016.

Successful Delivery Reward Criteria continued

Criteria 9.3

SESG State Estimator Developed Successfully

The state estimator enabling the monitoring of the South East network at both transmission and distribution level and determining the level of response required at different GSPs.

Evidence

- The state estimator developed and demonstrated in *Spectrum Power* (WP1B, beginning of October 2016)
- The state estimator has incorporated both transmission and distribution system (WP1B, beginning of October 2016)
- The state estimation enables the assessment of system behaviour against the following criteria (WP1B, beginning of October 2016)
  - Steady State Voltage
  - Dynamic Voltage Stability
  - Rotor-Angle stability
- The state estimator communicates in real time with monitoring devices and indicating the level of response at the GSP level (WP1B, beginning of October 2016)

Criteria 9.4

Response evaluation from Distributed Resources

The SESG is demonstrating how the use of distributed and transmission resources can have the potential to manage transmission constraints. The trial on distributed resources and understanding the capability of the resources to respond to signals sent by the state estimator will enable the key technical objective of the project.

Evidence

- **High level** trial design complete following completion of T1.4 to inform resource procurement process – January 2016
- **Detailed** trial design complete – August 2016
- The procurement process is established with list of potential service providers (WP1C, September 2016)
- Contracts signed between SESG and Service providers (WP1C, end of November 2016)
- Agreement with UKPN and response providers to respond to WP1b state estimator's signal (WP1C, end of November 2016)
- Trial carried out at system states indicated by WP1a (WP1C, end of October 2017)
- Response recorded and validated (WP1C, end of October 2017)

Criteria 9.5

Successful development of new Commercial Services to enable the use of Distributed Resources

To enable the roll out of the SESG concept, the new commercial services which incentivise the service providers (distributed resources) to provide response to the transmission system will be developed.

Evidence

- New commercial service with detailed description of the service type, duration, and payment methodology developed (WP2, August 2017)

Criteria 9.6

Successful Roll Out Plan Developed

The immediate areas for deployment of SESG concept identified, and the Network Development Policy (NDP) is enabled to perform the assessment of SESG concept as a non-build solution.

Evidence

- Developing non-build solution under NDP; enabling least regret assessment alongside transmission solutions (WP3, beginning of October 2017)
- The roll out plan including the sites, degree of benefit and dates identified (March 2018)

Criteria 9.7

Successful Knowledge Dissemination of SESG

Successful dissemination of knowledge generated by SESG within National Grid, to other transmission owner, DNOs, and industry stakeholders will be carried out to ensure the learnings are communicated at different stages of the project to enable timely roll out of the non-build solution concept.

Evidence

- Knowledge sharing e-hub developed (March 2015)
- All non-confidential data, and models developed as part of SESG to be shared on the e-hub (End of the project, March 2018)
- Work package reports delivered at the end of each work package and made available on the e-hub:
    - WP1A: Ongoing throughout the work package.

Successful Delivery Reward Criteria continued

- WP1B by October 2016
- WP2 by August 2017
- WP1C & WP3 by March 2018

- Smart Grid Training Programme based on SESG developed for transmission planners using SESG facilities (WP3, by March 2018)
- Annual knowledge dissemination event (at least one per year) organised

Criteria 9.8

Project close and knowledge dissemination

The project is planned from January 2015 until March 2018. The project is well organised to satisfy all pre-set objectives and deadlines. Eventually the optimal management of South East network is demonstrated and the relevant commercial services are developed. The Smart Grid application used in South East can be trialled for other parts of network.

Evidence

- The project is assessed against its initial goal and objectives.
- All reports and findings are disseminated as appropriate and the final report is sent to authority.
- Project close down by March 2018.

Electricity Network Innovation Competition Full Submission Pro-forma

Section 10: List of Appendices

Appendix	Item and Short Summary
1	**Benefit Tables** *Fully populated according to template & guidance*
2	**Full Submission Spreadsheet <u>(Confidential)</u>** *Fully populated according to template & guidance*
3	**Project Plan** *A high level Project Plan of the main deliverables of each Work Package*
4	**Project Risk Register, Risk Management and Contingency Plans** *Detailed Risk Register with contingency plans and mitigation actions*
5	**Technical Description of the Project** *A detailed description of the project*
6	**Cost Benefit Analysis** *Analysis of the benefit of the SESG project*
7	**Organogram of the Project and Description of Partners** *More detail on the organisation of the project and the partners.*
8	**Letters of Support** *Letter of commitment from NGET and project partners as well as letters of support from project supporters*
9	**List of Previous Projects** *A list and high level summary of previous projects together with the learning that they bring to SESG*
10	**Detailed South East Map from UKPN** *A detailed map of the distribution and transmission assets in the South East area*

APPENDIX 1: Benefit Tables

KEY

Method	Method name
Method 1	Transmission and Distribution System Monitoring and State Estimator (WP1a + WP1b)
Method 2	Coordinated use of Transmission and Distribution Resources (WP1+WP2+WP3)

Electricity NIC – financial benefits

Financial benefit (£m)								
Scale	**Method**	**Method Cost**	**Base Case Cost**	**Benefit**			**Notes**	**Cross-references**
				2020	**2030**	**2050**		
Post-trial solution *(individual deployment)* *Limited to South East of the Network (SESG's direct benefit)*	Method 1	4.75	14	7.25	67.25	187.25	The benefit for Method 1 alone has been assumed to be limited to savings on steady state voltage support (extremely conservative and could be 2-3 times higher savings). This is based on **£6m savings** per annum (as presented in Appendix 6.3), and total savings based on change in reactive demand. This is the inherent savings resulted by SESG. The benefit for Method 2 is assumed to be the savings in capital cost of building the new line [£500m] – the need case for the line is anticipated to be post-2020. It is expected that payment to service providers to be in the region of £30/MWh – and the SESG to be armed 10% of times based on 300MW of service provider contracts = **£7.8m**/annum. Figures are 2014 prices.	Table 3-1 on page 19 of the main document has the full list of spending on capital cost of new assets/constraints which are used to determine the savings can be achieved from this project. Refer to Appendix 6 for a detailed breakdown of all the base case costs. The 300MW figure is based on the preliminary study carried out to determine the level of response requirement. The £30/MWh is the estimated average service cost based on the average cost of constraint action. As part of WP2, the exact value of the required services will be determined.
	Method 2	10.3+7.8 (service cost annually)	500	0	396	240		
GB rollout scale *Roll out to at least 4 areas of the GB power system* *1 extra site between 2021-2030* *Three additional sites between 2031-2050*	Method 1	16	35	70	350	700	Number of sites: 4 – Assumed reduction of 10% reduction in method cost for roll out to GB scale – The savings on method 1 is based on spending on managing high volts in 2012/13 (circa £35m/annum) – This is expected to increase significantly, but to have a conservative figure the 2012/13 figures are used (low end) The savings for GB roll out scale has been scaled up based on the one more site between 2021-2030 and three additional sites post 2030.	
	Method 2	37	500 per site	0	421	1032		

Electricity NIC – carbon and/or environmental benefits

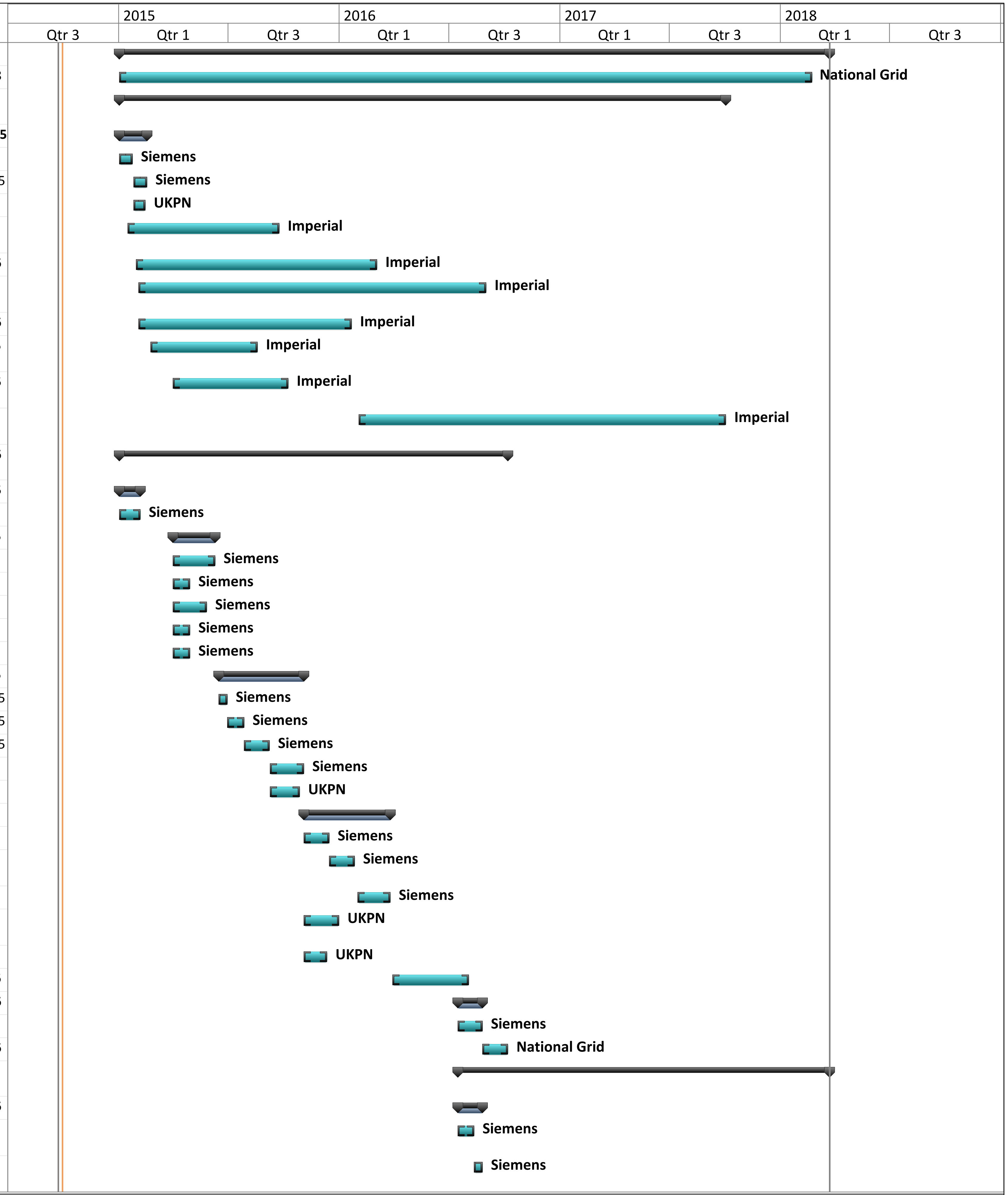
Energy Saved (kWh)								
Scale	**Method**	**Method Cost**	**Base Case Cost**	**2020**	**2030**	**2050**	**Notes**	**Cross-references**
Post-trial solution *(individual deployment)* *Limited to South East of the Network (SESG's direct benefit)*	Method 1	£4.75m	£14m	432×10^6	$2{,}161 \times 10^6$	$4{,}323 \times 10^6$	The energy savings for Method 1 are calculated based on the savings made in constraining generators to run for voltage control. It has been assumed just less than 5% of the total reactive power contracted was as a result of direct constraining the generators in order to get a conservative level– in reality it is much higher level – and will increase in the future. For Method 2, the energy saving level associated with accommodating more interconnectors and renewables is presented. The energy savings reflect as of 2028 has taken into account IFA2 connection to the South East. The benefits are over the number of years indicated in the table.	The calculation of the CO_2 savings figures are presented in Section 4a, page 21 of the main document.
	Method 2	£10.3m+£7.8m (service cost annually)	£500m	17.2×10^9	119×10^9	299×10^9		
GB rollout scale *Roll out to at least 4 areas of the GB power system* *1 extra site between 2021-2030* *Three additional sites between 2031-2050*	Method 1	£16m	£35m	$2{,}543 \times 10^6$	$12{,}714 \times 10^6$	$25{,}429 \times 10^6$	Number of sites: 4 – The savings on method 1 is based on spending on managing high volts in 2012/13 (circa £35m/annum) – This is expected to increase significantly, but to have a conservative figure the 2012/13 figures are used (low end) The savings for GB roll out scale has been scaled up based on the one more site between 2021-2030 and three additional sites post 2030.	
	Method 2	£37m	£500m per site	17.2×10^9	238×10^9	$1{,}196 \times 10^9$		
If applicable, indicate any carbon and/or environmental benefits which cannot be expressed as kVA or kWh.	**Post-trial solution:** [Explain any carbon and/ or environmental benefits which cannot be expressed as kVA or kWh]							

Electricity NIC – carbon and/or environmental benefits

Carbon Savings equivalent $MtCO_2$								
Scale	**Method**	**Method Cost**	**Base Case Cost**	**2020**	**2030**	**2050**	**Notes**	**Cross-references**
Post-trial solution *(individual deployment)*	Method 1	£4.75m	£14m	0.204 $MtCO_2$	1.02 $MtCO_2$	2.04 $MtCO_2$	The carbon savings for Method 1 are calculated based on the savings made in constraining generators to run for voltage control and reduction in CO_2 level. For Method 2, the reduction in CO_2 level associated with accommodating more interconnectors and renewables is presented. The CO2 savings as of 2028 has taken into account IFA2 connection to the South East.	The calculation of the CO_2 savings figures are presented in Section 4a, page 21 of the main document.
	Method 2	£10.3m+£7.8m (service cost annually)	£500m	18 $MtCO_2$	96 $MtCO_2$	240 $MtCO_2$		
GB rollout scale *If applicable, indicate the number of relevant sites on the GB network.*	Method 1	£16m	£35m	1.19 $MtCO_2$	5.97 $MtCO_2$	11.95 $MtCO_2$	Number of sites: 4 – The savings on method 1 is based on spending on managing high volts in 2012/13 (circa £35m/annum) – This is expected to increase significantly, but to have a conservative figure the 2012/13 figures are used (low end) The savings for GB roll out scale has been scaled up based on the one more site between 2021-2030 and three additional sites post 2030.	
	Method 2	£37m	£500m per site	72 $MtCO_2$	360 $MtCO_2$	720 $MtCO_2$		
If applicable, indicate any carbon and/or environmental benefits which cannot be expressed as kVA or kWh.	**Post-trial solution:** [Explain any carbon and/ or environmental benefits which cannot be expressed as kVA or kWh]						Further environmental benefits associated with SESG project include avoidance of: • Land use; • Noise; • Public health and safety; • Damage to sensitive plants and animals; • Soil erosion; • Visual impact.	
	Licensee scale: [Explain any carbon and/ or environmental benefits which cannot be expressed as capacity or kVA or kWh]							
	GB rollout scale: [Explain any carbon and/ or environmental benefits which cannot be expressed as kVA or kWh]							

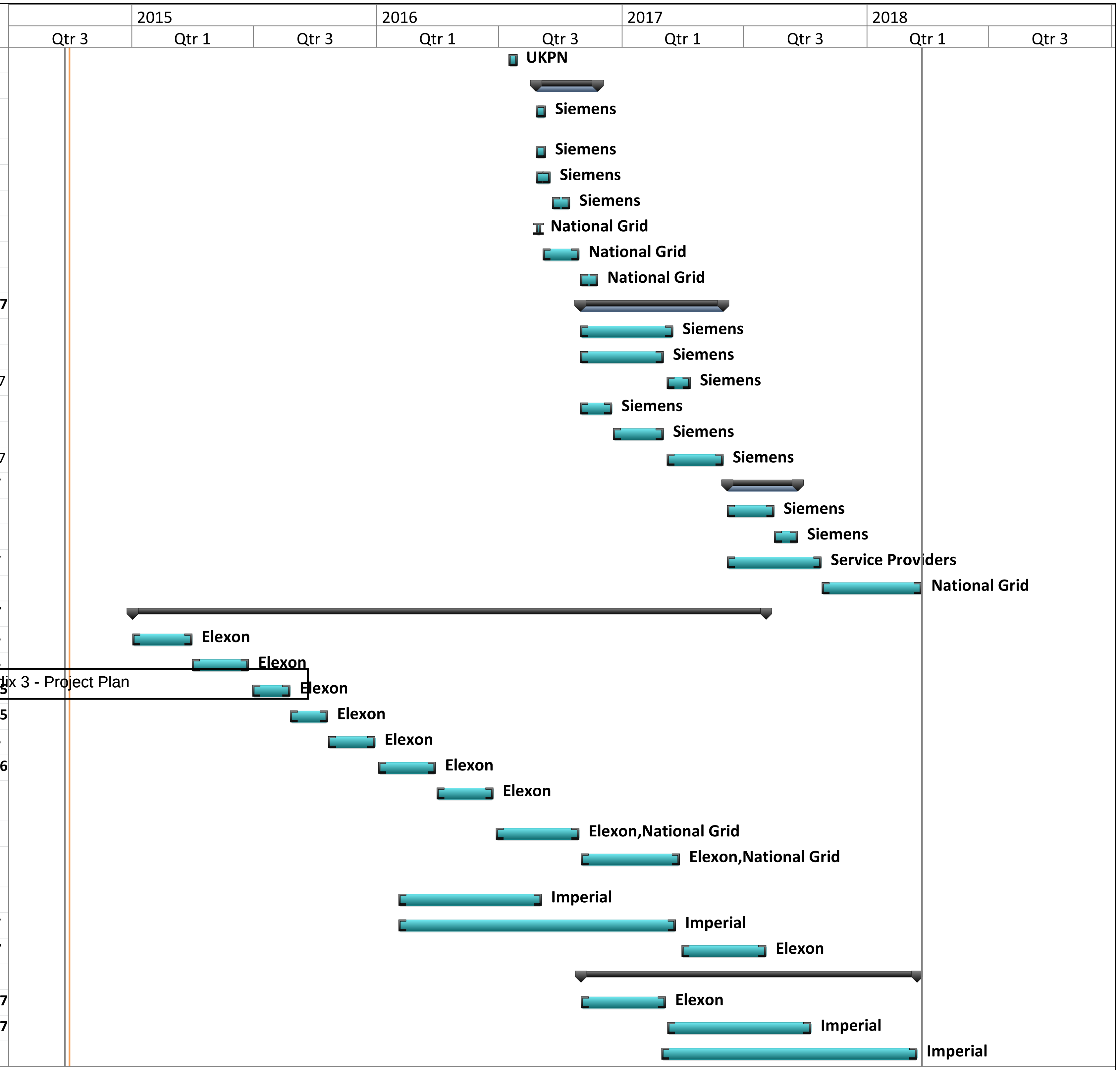
Appendix 3 - Project Plan

ID	Task Name	Duration	Start	Finish
1	**NIC - SESG**	**841 days**	**Fri 02/01/15**	**Fri 23/03/18**
2	**Project Management - NGET**	**820 days**	**Fri 02/01/15**	**Thu 22/02/18**
3	**WP1A - Development of Tools and Techniques for Whole System Evaluation**	**717 days**	**Fri 02/01/15**	**Mon 02/10/17**
4	**WP1A - Solution Development**	**32 days**	**Fri 02/01/15**	**Mon 16/02/15**
5	Assess Current GSP Monitoring Capabilities	16 days	Fri 02/01/15	Fri 23/01/15
6	Identify Required Additional GSP and Resource Monitoring Points	16 days	Mon 26/01/15	Mon 16/02/15
7	Validate NG model including SPN distribution network	15 days	Mon 26/01/15	Fri 13/02/15
8	**T1.1 - Develop detailed computer simulation models for the South East network**	**179 days**	**Fri 16/01/15**	**Wed 23/09/15**
9	**T1.2 - Identification of optimal locations for installing monitoring devices**	**285 days**	**Fri 30/01/15**	**Thu 03/03/16**
10	**T1.3 - Development of Virtual Power Plant concept for large and small/medium generators**	**412 days**	**Tue 03/02/15**	**Wed 31/08/16**
11	**T1.4 - Analysis of monitoring and control systems in South East network**	**253 days**	**Tue 03/02/15**	**Thu 21/01/16**
12	**T1.5 - Extend existing network simulator for real-time simulation of the South East network**	**127 days**	**Mon 23/02/15**	**Tue 18/08/15**
13	**T1.6 - Integrate physical hardware with real-time simulation to prepare a HIL platform**	**137 days**	**Wed 01/04/15**	**Thu 08/10/15**
14	**T1.7 - Validate network montoring and coordinated control through HIL and software based simulation**	**434 days**	**Wed 03/02/16**	**Mon 02/10/17**
15	**Work Package 1B - Wide Area Monitoring across South East (T&D State Estimator)**	**460 days**	**Fri 02/01/15**	**Thu 06/10/16**
16	**WP1B - Solution Development**	**25 days**	**Fri 02/01/15**	**Thu 05/02/15**
17	Monitoring Concept Functional Description Production / Workshop	25 days	Fri 02/01/15	Thu 05/02/15
18	**WP1B - Detailed Design**	**50 days**	**Wed 01/04/15**	**Tue 09/06/15**
19	Configuration of Central Management System	50 days	Wed 01/04/15	Tue 09/06/15
20	Procurement of Monitoring Hardware	20 days	Wed 01/04/15	Tue 28/04/15
21	Detailed Design Documentation Development	40 days	Wed 01/04/15	Tue 26/05/15
22	Site Assessments	20 days	Wed 01/04/15	Tue 28/04/15
23	Procurement of Central Control Hardware and Software Licences	20 days	Wed 01/04/15	Tue 28/04/15
24	**WP1B - Design Freeze & Delivery**	**101 days**	**Tue 16/06/15**	**Tue 03/11/15**
25	Configuration of System Monitoring Solution	10 days	Tue 16/06/15	Mon 29/06/15
26	Design of Remote Monitoring Modules	20 days	Tue 30/06/15	Mon 27/07/15
27	Manufacture of Remote Monitoring Modules	30 days	Tue 28/07/15	Mon 07/09/15
28	Factory Acceptance Testing	40 days	Wed 09/09/15	Tue 03/11/15
29	Design for PMU installation	35 days	Wed 09/09/15	Tue 27/10/15
30	**WP1B - Site and Commissioning**	**103 days**	**Wed 04/11/15**	**Fri 25/03/16**
31	Installation of Monitoring and Control Hardware	30 days	Wed 04/11/15	Tue 15/12/15
32	Interfacing to third party systems (i.e. GE XA21) and GSP Interface Device	30 days	Wed 16/12/15	Tue 26/01/16
33	Commissioning and SAT of installed system	40 days	Mon 01/02/16	Fri 25/03/16
34	Site access and Supervision by SAP during installation of PMUs (UKPN)	42 days	Wed 04/11/15	Thu 31/12/15
35	Commissioning of PMUs (UKPN)	28 days	Wed 04/11/15	Fri 11/12/15
36	**WP1B - Trials**	**90 days**	**Wed 30/03/16**	**Tue 02/08/16**
37	**WP1B - Assessment**	**30 days**	**Sat 16/07/16**	**Thu 25/08/16**
38	Evaluate soak period findings and validation	30 days	Sat 16/07/16	Thu 25/08/16
39	**WP1B - Learning dissemination**	**30 days**	**Fri 26/08/16**	**Thu 06/10/16**
40	**Work Package 1C - Coordinated Control of Transmission and Distribution Resources**	**440 days**	**Sat 16/07/16**	**Fri 23/03/18**
41	**WP1C - Solution Development**	**30 days**	**Sat 16/07/16**	**Thu 25/08/16**
42	Evaluate Co-ordinated Distributed Resource Response (DRR) requirements	20 days	Sat 16/07/16	Thu 11/08/16
43	Distributed Resource Response Functional Description Production / Workshop	10 days	Fri 12/08/16	Thu 25/08/16



Appendix 3 - Project Plan

ID	Task Name	Duration	Start	Finish
44	Network Analysis to Support Site Selection (UKPN)	10 days	Sat 16/07/16	Thu 28/07/16
45	**WP1C - Detailed Design**	**66 days**	**Fri 26/08/16**	**Fri 25/11/16**
46	Procurement of Hardware / Software Licences for DNO Control Enablement	10 days	Fri 26/08/16	Thu 08/09/16
47	Procurement of Hardware for Distributed Resources	10 days	Fri 26/08/16	Thu 08/09/16
48	Detailed Design Documentation Development	15 days	Fri 26/08/16	Thu 15/09/16
49	Site Assessments	20 days	Mon 19/09/16	Fri 14/10/16
50	Invitation to tender to Service Providers for Service Trials	5 days	Fri 26/08/16	Thu 01/09/16
51	Tender Process of Service Providers	40 days	Mon 05/09/16	Fri 28/10/16
52	Contract Award to Service Providers for Service Trials	20 days	Mon 31/10/16	Fri 25/11/16
53	**WP1C - Design Freeze & Delivery**	**153 days**	**Mon 31/10/16**	**Wed 31/05/17**
54	Configuration of DNO Control Enablement	100 days	Mon 31/10/16	Fri 17/03/17
55	Configuration of Distributed Resource Response Function Type	90 days	Mon 31/10/16	Fri 03/03/17
56	Configuration of Distributed Resource Response Units	25 days	Thu 09/03/17	Wed 12/04/17
57	Design of Enhanced control cubicles	35 days	Mon 31/10/16	Fri 16/12/16
58	Manufacture of Enhanced control cubicles	55 days	Mon 19/12/16	Fri 03/03/17
59	Factory Acceptance Testing of Enhanced Control Functionality	60 days	Thu 09/03/17	Wed 31/05/17
60	**WP1C - Site and Commisioning**	**75 days**	**Wed 07/06/17**	**Tue 19/09/17**
61	Installation and Commissioining of Enhanced Control Hardware	50 days	Wed 07/06/17	Tue 15/08/17
62	Test and Demonstrate Response Capability	25 days	Wed 16/08/17	Tue 19/09/17
63	**WP1C - Trials**	**100 days**	**Wed 07/06/17**	**Tue 24/10/17**
64	**WP1C - Learning Dissemination**	**107 days**	**Thu 26/10/17**	**Fri 23/03/18**
65	**Work Package 2 - Development of Commercial Tools and Services**	**675 days**	**Fri 02/01/15**	**Thu 03/08/17**
66	**Define commercial questions and market review questions**	**63 days**	**Fri 02/01/15**	**Tue 31/03/15**
67	**Phase One: Assessment of cross-party savings, impacts and innovations**	**60 days**	**Wed 01/04/15**	**Tue 23/06/15**
68	**Performance assurance**	**40 days**	**Tue 30/06/15**	**Mon 24/08/15**
69	**TSO, DNO and Suppliers**	**40 days**	**Tue 25/08/15**	**Mon 19/10/15**
70	**Future Balancing Mechanism**	**50 days**	**Wed 21/10/15**	**Tue 29/12/15**
71	**Phase Two: Commercial modelling**	**61 days**	**Mon 04/01/16**	**Mon 28/03/16**
72	**Review Phase 1 and Phase 2 reports in stakeholder workshops and update assumptions**	**60 days**	**Thu 31/03/16**	**Wed 22/06/16**
73	**Workshops and detailed design documentation**	**90 days**	**Mon 27/06/16**	**Fri 28/10/16**
74	**Detailed specifications**	**105 days**	**Tue 01/11/16**	**Mon 27/03/17**
75	**T2.1 - Development of commercial arrangements**	**153 days**	**Wed 03/02/16**	**Fri 02/09/16**
76	**T2.2 - Option value of SESG Contracts**	**295 days**	**Wed 03/02/16**	**Tue 21/03/17**
77	**Final report on market arrangement questions**	**90 days**	**Fri 31/03/17**	**Thu 03/08/17**
78	**Work Package 3 - Need Case Development for Rollout to Other Areas**	**359 days**	**Tue 01/11/16**	**Fri 16/03/18**
79	**Presentation & Promotion of findings to Key Stakeholders**	**90 days**	**Tue 01/11/16**	**Mon 06/03/17**
80	**T3.1 - Risk Profile of SESG solutions**	**152 days**	**Fri 10/03/17**	**Mon 09/10/17**
81	**T3.2 - Roll out plan of SESG paradigm**	**273 days**	**Wed 01/03/17**	**Fri 16/03/18**



Appendix 3 - Project Plan

Appendix 4: Project Risk Register, Risk Management and Contingency Plans

Project : South East Smart Grid

As At: 02-Oct-14

Risk No.	WorkStream/ Area	Risk Description	Cause	Consequence	Status (O/C)	Risk Owner	Likelihood (1-5)	Financial Impact (1 - 5)	Reputational Impact (1 - 5)	RAG	Escalate To	Action Plan	Control Opinion
1	General	There is a risk that any partner/s might pull out of tduring the submission or during the project implementation	Because of various reasons such as different contractual arrangements or change in priorities	Leading to not having a partner and having to procure the service through procurement	Open	Project Manager	2	1	2	4	Project Manager	During the project planning phase, NG to engage with UKPN to establish the optimum times for running trials with minimum risk to QoS - Alternative would be to tender for new participants	Effective
2	General	Access to identified Substations and Plant for installation of monitoring equipment is not available within the programme timescales	Plant outages not granted or available when required and / or NG site resource unavailable	Programme slip to complete installation of Monitoring equipment	Open	Project Manager	3	1	3	9	Working Group	Outages and resource to be booked specifically for SESG work and not rely too heavily on 'piggy backing' third party outages	Effective
4	General	Significant changes to the GB electricity system during the life of the project.	Priorities or strategies for planning and managing the GB system may change.	Solution may no longer be suitable. Assumptions may no longer be accurate or appropriate.	Open	Project Manager	1	3	4	4	Project Manager	We have fully considered future developments and scenarios. We have ensured usefulness of solution matches planning of system.	Effective
5	General	National Grid and/or the partners do not allocate sufficient resources for the project in time.	Resources have other commitments	Project does not start in a timely manner	Open	Project Manager	1	2	3	3	Project Manager	A project plan has been produced and partners have been asked to allocate resources to achieve the milestones	Effective
6	General	Technical specification (TS) being either to abstract or too descriptive.	Insuficient engagement with partners in preparing the TS	Specific issues may be unaccounted for due to an ambiguous specification. On the other hand, if the TS is too descriptive, this could prohibit further innovation from the different parties as it would restrict ingenuity.	Open	NG	2	3	2	6	Project Manager	Produce a technical specification that has inputs from different areas of the business as well as from the different partners, ensuring that it is not too prescriptive so as to impede further innovation during delivery of the project	Effective
7	General	Critical staff leave National Grid or our project partners during project lifecycle.	Usual and unavoidable staff turnover results in key staff leaving National Grid or our project partners.	Progress of the project is delayed. The expertise to deliver the project is no longer within the project team.	Open	Project Manager	2	2	3	6	Project Manager	Knowledge of, and rsponsibility for, project to not rely with one person. Ensure documentation and guidance exists to assist anyone joining project team. Thorough handover processes to be in place.	Effective
8	General	Equipment required for the project is not delivered in time	Supplier constraints or lack of early communication	Delay to the project milestones	Open	Project Manager	3	2	4	12	Working Group	Siemens has been selected as the partner and technology provider and has been made aware of all project milestones, ensuring that equipment will be available when required in the project.	Effective
9	General	Estimated costs are substantially different to actual costs.	Full scope of work is not understood; cost estimates are not validated; project is not managed closely.	Potential project funding gap. Alternative funding is required or the project scope is reduced.	Open	Project Manager	3	3	4	12	Working Group	Ensure cost estimates are thorough and realistic and reflect full scope of work. Validate estimates based on tenders and market knowledge. Appropriate contingency to be included.	Effective

Appendix 4: Project Risk Register, Risk Management and Contingency Plans

Project : South East Smart Grid

As At: 02-Oct-14

Risk No.	WorkStream/ Area	Risk Description	Cause	Consequence	Status (O/C)	Risk Owner	Likelihood (1-5)	Financial Impact (1 - 5)	Reputational Impact (1 - 5)	RAG	Escalate To	Action Plan	Control Opinion
10	General	Knowledge gained from project is not adequately shared with industry and other interested parties.	Poor engagement with stakeholders	A major benefit of the project is lost. Performance of solution and lessons learned are not shared.	Open	NG	2	3	4	8	Working Group	Knowledge sharing has been included in the project plan to disseminate knowledge throughout the development of the project. In addition, Imperial College has been selected to lead on knowledge dissemination	Effective
11	WP1A	Imperial College cannot receive a dynamic model of the transmission and distribution systems to commence simulation works	The models are confidential to both National Grid and UKPN	Value of the project reduced since WP1A would not be able to proceed.	Open	Imperial College	2	2	3	6	Project Manager	This risk will be mitigated via project contracting through a well tested process in the management of data confidentiality	Effective
12	WP1A	Unable to model the South East network with sufficient detail using the RTDS facilities.	Lack of expertise in Imperial College	Wide scale rollout may be severely impacted by issues not flagged during the validation phase.	Open	Imperial College	1	2	3	3	Project Manager	Imperial College is a well known expert in power systems with extensive experience in real time analysis so the risk is unlikely.	Effective
13	WP1B	There is a risk that planning issues could compromise the optimal positioning of equipment in the network.	Planning authority does not approve planning permission.	Delay to project milestones and/or impact on the success of the project.	Open	NG	3	2	3	9	Working Group	National Grid will ensure to ensure that the general public is informed of the works that will be carried out to reduce risk of objections. The contingency will be to identify alternative locations for the equipment in case planning permission is not approved.	Effective
14	WP1B/C	Spectrum Power standard TNA applications require adaptation for SESG	Be-spoke requirements of project objectives	Software development work and programme delay	Open	Siemens	2	1	3	6	Project Manager	Functional Requirements of solution to be finalised as early as possible to allow experts to adapt standard function to suit objectives of SESG	Effective
15	WP1B/C	Technical limitations of ICCP interoperabillity between proposed Spectrum Power Central Controller and NG GE NMS communications link	ICCP standard implementation on hardware / software platform	Software development work and programme delay	Open	Siemens / NG	3	1	2	6	Project Manager	ICCP Trial Workshop involving all affected stakeholders to ensure interoperability early	Effective
16	WP1C	Security of Supply commitments of Stakeholders (NG & UKPN) are compromised during trials of controllable end to end solution	Trials held at unsuitable times (Heavy load period)	Detrimental effect to quality of supply on Transmission / Distribution network	Open	NG / UKPN	2	4	4	8	Working Group	During the project planning phase, NG to engage with UKPN to establish the optimum times for running trials with minimum risk to QoS	Effective
17	WP1C	Delivery of Optimisation Model development may be delayed / cancelled at Work package 1C	Learning objectives of Monitoring phase and DRR evaluation are not achieved during Stage 1	- Programme slip and costs - Funding for WP2 not given	Open	Siemens / NG	3	3	3	9	Working Group	Close monitoring of model developments - ensure delivery gates are closely monitored particularly those related to this work package	Effective
18	WP1C	Integrity of supply in the controllable GSP area put at risk during Optimisation testing	Request for constraint generation / demand too great on a localised part of the distribution network	Reputational and Financial costs	Open	NG / Siemens	2	4	4	8	Working Group	Analysis of optimum number and network location of resource to be controlled to generate desired impact on transmission network without affecting local distribution network integrity	Effective

Appendix 4: Project Risk Register, Risk Management and Contingency Plans

Project : South East Smart Grid

As At: 02-Oct-14

Risk No.	WorkStream/ Area	Risk Description	Cause	Consequence	Status (O/C)	Risk Owner	Likelihood (1-5)	Financial Impact (1 - 5)	Reputational Impact (1 - 5)	RAG	Escalate To	Action Plan	Control Opinion
19	WP1C	Poor response from service providers (demand side response/ storage/etc.) when invited to Tender.	Lack of interest from service providers due to poor initial engagement	Trials would not be able to proceed and project may need to be cancelled	Open	NG	3	3	2	9	Working Group	Ensure early engagement with service providers to capture interest before invitation to tender.	Effective
20	WP1C	Coordination between transmission and distribution systems not achieved.	Lack of experience in coordinating between transmission and distribution systems/ DNO is not willing to cooperate.	Value of the project reduced as WP1C would not be successful.	Open	NG / UKPN	3	3	4	12	Working Group	Extensive studies will be carried out in WP1A to generate knowledge that will guide the rest of the project and ensure a successful outcome. In addition, UKPN is a partner to the project and has agreed to provide support.	Effective
21	WP1C	Technology used in the project (i.e. the software developed on Siemens' Spectrum Power Platform) does not perform as expected during the commisioning stage.	Unproven technoloogy	Impact to the quality of the outputs of the project	Open	Siemens / NG	2	3	3	6	Project Manager	There is a vast amount of knowledge gathered by both National Grid and the project partners which will ensure success at the commisioning stage. In addition, the simulations carried out in WP1A will ensure that the technology is fit for purpose and will perform well.	Effective
22	WP2	Access to control or call upon services to enable end to end trialling of SESG is denied	- Commercial issues - Suitability of services available (DSR, Storage, Generator output, etc.)	Project objectives not fully realised	Open	NG	3	2	3	9	Working Group	- Assessment and identification of available services / resources early as possible. - Engagement with potential service providers which are planned to be delivered during lifecycle of SESG.	Effective
23	WP3	Technology developed for the South East cannot easily be rolled out to other areas of the network	Technology not being developed with rollout other areas in mind.	Value of the project reduced since rollout in WP3 would not be possible.	Open	NG	3	3	4	12	Working Group	A technical specification will include the criteria that the technology must be extendable to other areas. In addition, WP3 will be delivered in parallel, ensuring that the technology developed has always other areas of the network in mind	Effective

Definitions

Impact	
1	L
2	M
3	M
4	H
5	H

Likelihood	
1	L
2	M
3	M
4	H
5	H

Score	RAG
1 - 6	
7 - 14	
15 - 25	

Impact \ Likelihood	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

Control Opinion
Effective
Partially Effective
Not Effective

Reputation Impact Ratings

Score	Description	Definition
1	Internal	Internal - minor impact on stakeholders within NGT Group
2	Intra-Group	Internal - major impact on stakeholders within NGT Group
3	Local third party	External - impact on local stakeholders
4	National	External - impact on national stakeholders
5	International	External - impact on international stakeholders

Financial Impact Ratings

Score	£m
1	0 to 5
2	5 to 10
3	10 to 30
4	30 - 50
5	50+

Likelihood Impact Ratings

Score	Description	Frequency of Occurrence	Probability of Occurrence
1	Remote	<Once in 20 years	<10% chance
2	Less Likely	<Once in 15 years	>10% and <40% chance
3	Equally Likely as Unlikely	<Once in 10 years	>40% and <60% chance
4	More Likely	<Once in 5 years	>60% and <90% chance
5	Almost Certain	One or more a year	>90% chance

CONTROL OPINION

Not Effective	Key controls have not been established or are deemed to be ineffective. Action plans to rectify the fundamental weakness have still to be fully implemented
Partially Effective	Key controls are in place but have either not been subject to suitable assurance activity or testing reveals that some control improvements, not deemed to be fundamental, are required
Effective	Key controls are in place, are tested periodically as appropriate and are deemed satisfactory. This testing includes independent challenge where the risk is deemed significant (e.g. from NG Audit or another independent assurance provider)

Project Code/Version No:
NGETEN02/V2

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 5: Technical Description

This Appendix provides some background information to guide the reader into concepts such as the Network Development Process, which is National Grid's "business as usual" process, as well as the current challenges facing the South East area of the network and the importance of the SESG project to resolve them. In addition, the scope of works of the SESG project are described in greater detail. The following is the list of sections that form this Appendix:

- A5.1 – The South East Network
- A5.2 – SESG Functional Overview
- A5.3 – Description of Trials
- A5.4 – Siemens' Solution Overview
- A5.5 – Imperial Scope Of Works
- A5.6 – Roll-out potential

A5.1 The South East Network

The Transmission System in Kent, see Figure A5-1, forms part of the transmission infrastructure which runs between the Greater Thames estuary, along the North Kent plain and on towards Sussex and to the South West.

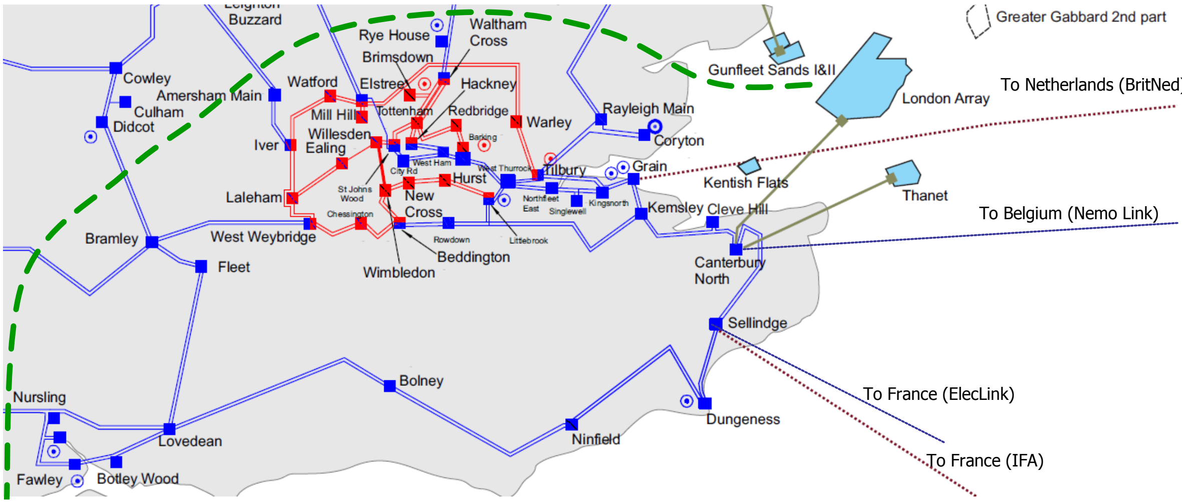


Figure A5-1 South East Network Map

History

The Transmission System in the area was originally constructed in the 1960s and the first Dungeness A nuclear power station (now in the process of decommissioning) was connected to the network in 1965. The Transmission System was subsequently upgraded in 1972 to provide a connection to Dungeness B nuclear power station. It also provides a connection to the 2000MW interconnector between England and France at Sellindge.

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 5: Technical Description Continued

Challenges

National Grid has licence obligations to seek to operate the network at all times in a manner consistent with the NETS SQSS[1] and Grid Code obligations including those associated with Frequency and voltage regulation and containment. In the case where exceptional events occur, National Grid also will separately report to Ofgem[2]. National Grid further reports the on the availability of its system within its annual report[3] and has recently submitted to Ofgem its 2014 data, which includes the annual availability statistics relating to its system in Table 5.2.

In addition to those national statistics, National Grid further reports specific to the South East region in consideration under its bilateral Nuclear Site Licence Provisions Agreements (NSLPA) with EDF and Magnox, as referenced in the EDF statement of support shown in Appendix 8 of this document. In this NSLPA dialogue, National Grid reports on all fault events occurring in an area and supports the Nuclear Industry in the analysis of these events to support and further technical understanding of the performance of the transmission system appropriate to supporting the nuclear licensee safety case considerations.

In support of the statistics detailed in these reports, National Grid can state that the South East Coast (the area between Kemsley 400kV substation in Kent and Lovedean 400kV) is currently experiencing challenges such as high voltage at low to moderate demand level. In addition, high transfers across the interconnectors could result in severe disturbances following a transmission fault.

Example incident

To illustrate the challenges in this area, a well documented incident that occurred in the South East network will be presented. This event occurred on 30th September 2012, 15:03 in the afternoon. At a national system demand of 32.9GW, a fault occurred on the French side of the UK – France CSC type link at the Les Mandarins RTE substation affecting the Bipole 2 connection at the French end of the network. At this time both HVDC convertor bipoles were fully importing 1000MW each to the GB transmission system. Figure A5-2a describes the frequency behaviour of the GB system across this incident.

The effect of the fault was to instantaneously remove approximately 2000MW of power from the UK transmission system as both Bipole power levels collapsed to 0MW, given that the transmission voltage across Les Mandarins remained at 0MW during the fault. Within circa 100ms, the fault was locally cleared allowing the un-faulted Bipole 1

[1] NETS Security and Quality of Supply Standard Available at: http://www2.nationalgrid.com/UK/Industry-information/Electricity-codes/SQSS/The-SQSS/

[2] Electricity Transmission Operational Data – Performance Reports. Available at: http://www2.nationalgrid.com/UK/Industry-information/Electricity-transmission-operational-data/Report-explorer/Performance-Reports/

[3] National Grid Annual Reports: http://investors.nationalgrid.com/reports/2013-14/plc.aspx

associated with the UK- France HVDC to restore its output within approximately 300ms of the fault under fast-ramping action, containing the net Frequency loss at 1000MW at this point. The Frequency on the GB system initially fell from 49.97Hz to 49.61Hz (Figure A5-2a), however the rapidity of the rate of frequency fall is also of note, in addition to the presence of a second dip in the frequency trace (between 14.04 and 14.05 hours) illustrates the risk of exacerbating effects derived from the automatic disconnection of distributed generation resources across the period of the incident. Table A5-1 describes the variation of frequency across the system, which was highly variable given that the South East itself was an electrically weak area of the system at the time with limited local transmission connected synchronous generation responding dynamically to the disturbance. The event detailed is an example within the RTE system of a widespread voltage dip leading to a frequency issue. For an electrical fault within the UK system however, given it is smaller and more highly meshed than the RTE system, the effect is potentially more significant. Figure A5-2b below describes the position in the South East system in response to a voltage depression.

National Grid simulates and manages the consequence of these effects in the day to day management of response and reserve holding on the network and in its compliance management and simulation of those connections that may experience fault ride through in response to system events to ensure that these issues do not combine to present a regional or GB wide instability risk.

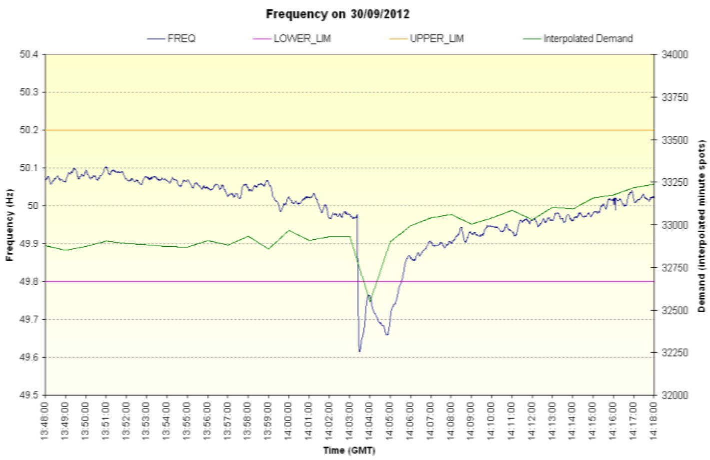


Figure A5-2a frequency trace during the 30/09/12 RTE incident

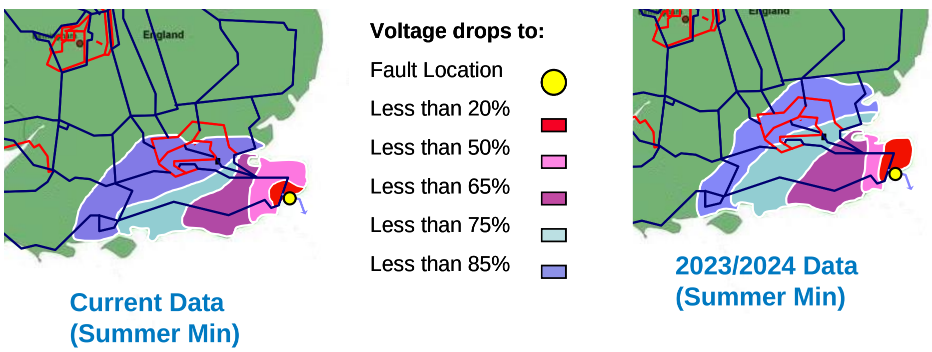


Figure A5-2b Extent of Voltage depression for a 3ph-e fault at Sellindge 400kV

Electricity Network Innovation Competition Full Submission Pro-forma
Appendix 5: Technical Description Continued

PMU	t=0 sample#	Frequency fo (Hz)	df/dt 500mS	df/dt 1000mS
LAGA L	1157	49.9620	0.1045	0.1013
LAGA A	1156	49.9790	0.1050	0.1018
HARK	1154	49.9729	0.1236	0.1183
SKLG	1157	49.9710	0.1182	0.1134
STAY2	1156	49.9790	0.1121	0.1082
STAY1	1156	49.9790	0.1122	0.1082
TYNE	1157	49.9750	0.1225	0.1173
BLYTH	1147	49.9750	0.1225	0.1173
		Average	**0.11506051**	**0.110712756**

PMU	t=0 sample#	Frequency fo (Hz)	df/dt 500mS	df/dt 1000mS
Brunel	1154	49.9816	0.1025	0.0995
Birmingham	1154	49.9810	0.1124	0.1083
Manchester	1157	49.9750	0.1182	0.1136
Strathclyde	1169	49.9710	0.1251	0.1190
		Average	**0.1145**	**0.1101**

Table A5-1 variation in the rate of change of frequency by event

Moving Forwards

Whilst no consumer load has been lost as a result of recent events upon the transmission system, of which that above is just one example, these events have seen the loss of generation and interconnector availability across the period of the events observed, which have in particular cases, shown periods of prolonged voltage depression following electrical faults in the South East areas or periods of simultaneous voltage depression with fast rates of frequency decay ahead of recovery. In addition, within the Distribution system, still further wind and solar generation projects are connecting, and at both Transmission and Distribution there is also significant intermittent demand arising from the electrification of transportation.

It is expected that new wind farms, and two new HVDC interconnectors will connect to this area of the network in the near future. These new connections have the potential to **exacerbate** existing voltage containment due to their inherent metereological/ commercial intermittencies which manifest themselves as a large range of effects on transmission flows in the area that may increase the effect of network gain in voltage, with the reactive power capability of these connections provided some offsetting of this effect but to a limited locality. Within the Distribution system, still further wind and solar generation projects are connecting, and at both Transmission and Distribution there is also significant intermittent demand arising from the electrification of transportation.

All the technical challenges discussed here have been included as part of the cost benefit analysis in Appendix 6.

Possible Solution (Business as Usual)

One possible transmission solution to this system area would be to introduce a new AC transmission route between the SE coast and the wider network. Such a route would be costly and would necessarily encounter delay risk in its development and implementation that could risk the timeframes of the connections in the area and access to the network in the intervening period. Another option that would provide intermediate benefit in managing the initial connections into the area would be to install an extensive scale of dynamic compensation operating within less than 100ms to support network behaviour- however such a solution would need to be very carefully designed and specified to avoid creating as well as resolving system issues and could not provide the extent of thermal capacity benefit a new AC transmission route would and that the area would appear to ultimately require.

Opportunity for a SMARTer Grid in the South East?

An alternative to this transmission solution is for the GBSO and England and Wales TO to engage proactively with the DNO in the area (UKPN) to implement **South East Smart Grid** principles.

The **South East Smart Grid** proposal represents a trial of potentially valuable areas of untapped resources including; targeted demand side management actions, dispatch of controllable resources including DNO, TO and generation dispatch and intertripping and auto-switching against wide area principles of overall South East transmission network. The trial of such co-ordination is proposed to be complemented by a roll-out of Phasor Measurement Units (PMUs) across the transmission network area to aid targeting of particular management options, and calculation of the effectiveness of those actions. The PMU data being available to such a widespread extent will further support the validation of the power system modelling being used to describe the system state in the area, supporting extrapolation of real-time experience into future year connection and network development scenarios. It is therefore the intention of SESG to combine improved monitoring of future events to understand in simulation and post event analysis, informed by the statistical record of past experience to map new and innovative applications of distribution resources to support the operation of the South East system.

Potentially the outcome of **South East Smart Grid** proposals could lead locally to:-

- Reduction of current operational costs in managing voltage control and local network inertia issues
- Identification of tuned Network reinforcement solutions
- Avoidance or deferment of new AC route investment dependent on the scale of connection activity
- Permitting some 4GW of additional interconnection capacity across the South East to have timely unrestricted access to the UK transmission system is expected to provide some £500m p.a. benefit in lowering energy prices to the UK consumer based on a recent study[4]. Refer to Appendix 6 for more details on this estimation.
- Identification of opportunities to maximise new connection capacity available across over any period during which a new AC route investment is being delivered.

[4] Getting More Interconnected, March 2014. http://www2.nationalgrid.com/About-us/European-business-development/Interconnectors/

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 5: Technical Description Continued

A5.2 SESG Functional Overview

This section details the high level functional operation of the proposed SESG and the interfaces which will be required to achieve the aims of the project, as detailed below.

Whilst there are a wide variety of technical challenges in the South East area, it is possible to summarise the effect of any disturbance arising from any of these conditions and the effect that SESG would have upon this situation in general terms. Figure A5-3 shows the four distinct operational network states (A, B, C & D) which occur before and after any disturbance. As shown in the figure, before a disturbance occurs (state A), the system remains in the 'normal' condition (green region). When the system suffers a disturbance (in state B), a rapid response is necessary in order to return the system to 'normal' (in state C) and further stabilised to reach state D.

Now, the actions taken to stabilise the system after a disturbance (in states B and C) will result in a reduction of the available resources that would respond to a second disturbance. This is depicted in the figure as a reduction of the 'normal' (green) region in state D. As the amount of European interconnection increases, the range of states the network may operate in grows and SESG will act to avoid operating in an unsafe condition.

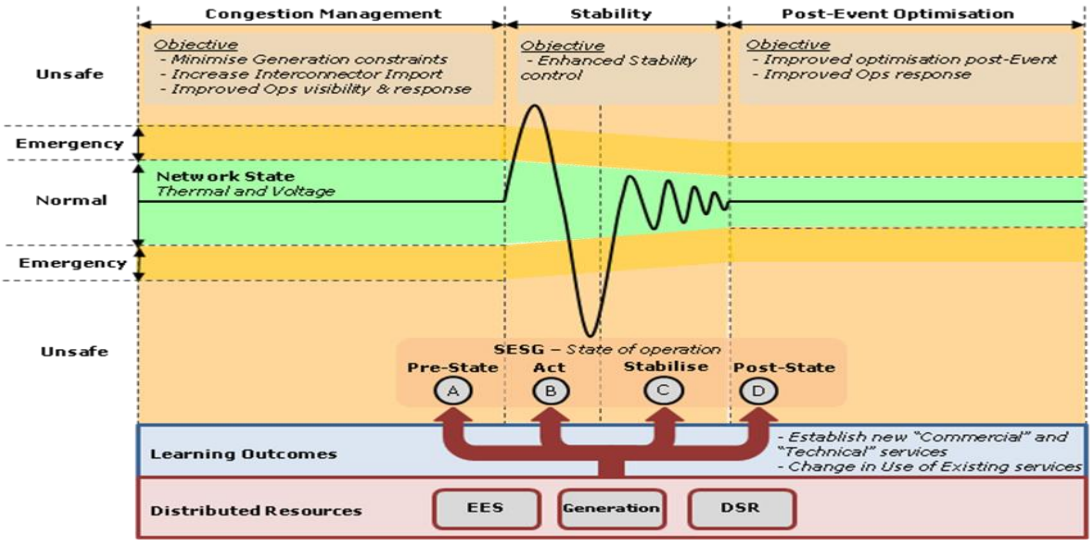


Figure A5-3 SESG Operational States

For each of these states, the SESG will provide optimisation in the way the unsafe condition is avoided:

State A, describes the normal, 'stable', operating state of the network in which thermal and voltage stability are conventionally managed by constraining generation in the South East area. SESG aims to minimise these constraints by co-ordination and use of distributed resources to manage the local network in such a way that voltage stability response is assured within the 'Normal' limits and to maximise the load flow contingency available for the transmission network. Using its enhanced 'Syncro-phasor' functionality for getting continuous updates, Siemens Wide Area Monitoring System (Phasor Measurement Unit and Phasor Data Processor) will be used to monitor sinusoidal input signals for Voltage and Current at 50Hz sample frequency, these measurements will be transferred to the Spectrum Power platform to determine the South East transmission network state and check if there are any thermal and/or voltage constraint issues. This contingency analysis is presented to the operator to take appropriate action, and is stored within the archive for future analysis by the operator and for validation by Imperial College London. The network monitoring points, transmission and distribution will be determined during Work Package 1A, considering the location and potential impact of distribution resources, that will be utilised in the evaluation and control trials, highlighted in Work Packages 1B and 1C. The application of distribution resources to achieve an optimised whole system network state will explore their relative value to enable the system stay within the enhanced 'normal' limit while in Pre-State A above.

States B & C, describe the stability response operating state of the network whereby an event (disturbance) has caused a loss in transmission connectivity, source or load and forced the network into instability. SESG aims to provide an enhanced response to a stability issue by increasing the range of resources available by using distributed resources such as Storage, Generation and DSR and reduce the effects that this condition has on the operation of the network. Trial design will assess stability response, based upon any actions taken prior to the event (i.e. State A), as well as utilisation of distributed resources during the stability state to support recovery, for example frequency response.

Additionally, the SIGUARD Phasor Data Processor (PDP) which acts as the central repository for arrangement and presentation of data from the Phasor Measurement Units (PMU) can be used as an alternative to site fault records for post-event analysis to visualise the network response with respect to effects on Voltage Profile and Circuit Loading during the Stability state.

State D describes the new post-event normal 'stable' operating state of the network whereby the transmission network topology has altered and the system 'Normal' limits have changed. SESG aims to provide an improved optimisation of network through use of distributed resources to support the restricted operating limits. Siemens Spectrum Power will use its inbuilt TNA application to optimally and actively balance demand with the dynamic distributed resources through real time optimal dispatch, hence putting the transmission system back into an optimised stable state (State D).

Physical Example

To further explain the effect SESG could have on the resilience of the network over States A-D, the following physical example is provided;

In the pre-state (A), the South East network may be subject to a requirement for transient voltage support following disturbance due to for example an initial condition of low demand and high power export out of the area. Ahead of the disturbance, actions to increase overall SE area demand would take place under SESG minimising the post disturbance overall voltage response necessary as compared to its requirement prior to SESG optimisation. Across the disturbance (let us assume a double circuit overhead line 3ph-e fault between Canterbury and Cleve Hill/ Kemsley), additional rapid measures such as intertripping of embedded generation and/or increased lagging power factor dispatch from distributed sources would be engaged within the area, which would have the added advantage across the period of the fault itself that whilst the transmission system voltage may be at or close to zero initially. The distribution system retained voltage would be higher due to its greater electrical distance from any transmission fault disturbance, allowing a greater array of responses from power electronic converted sources at that level in inherent response. This would all occur across the act phase (B).

Post eventual fault clearance, the scale of Mvar dispatch across the disturbance would need to be arrested, which will on power electronic devices experience delay in response due to control reference response to a developing progressive post fault clearance overvoltage. The SESG approach in monitoring and predicting the recovery would have identified subsequent corrective action, some of which could be obtained by distribution resources increasing the Mvar losses within the Grid supply points anticipated to be effective on the transmission problem for the short duration that that problem would manifest itself. This would represent the stabilise phase (C). In reaching the post state (D) following a permanent double circuit loss, the operator would seek to contain the frequency excursion resultant from a further double circuit loss which would entirely disconnect the overall south east export. In containing this risk in the post state SESG would make the operator aware of distribution level actions on MW remaining available post disturbance which could be used to minimise both risk period and overall level of transmission level MW re-dispatch.

It is recognised that the above is predominantly a general rather than specific discussion of disturbance and resource performance, however, each response will very much depend on the real-time network conditions and resource availability dictating the range of measures available. Following the completion of WP1A and WP1B it should be possible to discuss particular considerations to greater detail.

A5.3 Description of Trials

SESG trials will require service providers to make resource available (i.e. Demand in the case of DSR) for the purpose of trials. The service required (based on resource type) will be procured through a competitive tendering process and the payment to the users, will then effectively be the payment to the service providers.

- If the DSR service providers act as "aggregator" then the payment will be made directly to them based on the service they make available
- In case of an embedded generator, the payment will be made to the owner of the embedded generator, or if they are dispatched centrally via EG aggregators to the aggregator

The coordinated use of transmission and distributed resources aim to solve a range of network constraint issues. At the transmission level, the predominant issue in the South East in which SESG can deliver the most value is in the area of Voltage Control and stability (both steady state and dynamic).

<u>In the first instance</u>, measures such as coordinated tap control between HV/MV/LV network will be trialled, and then the coordinated use of distributed resources such as DSR, and embedded generation can be considered against optimal tap action having already been considered. The services expected from distributed resources such as DSR and embedded generation, are mainly related to the capability they can provide in terms of <u>changing their active power set-point</u>, which will have effect on the voltage on the transmission level - some larger sources closer to the connection point may also be able to influence voltage profile by reactive power dispatch.

<u>Our studies show the aggregated effect of reactive power change of large volume of the distributed generation, and particularly those which are installed relatively close to the GSPs can have great impact on managing voltage at the transmission level.</u> Therefore, one of the key objectives of WP1a is to determine the exact nature of services and the locations in which such services are required to deliver such effects when needed.

Trials would involve response to command initiation by the SESG controller, and on selected DSR and other distributed resources sites the necessary response (i.e. reduction of demand, or increase in demand) will be explored and demonstrated. The trials will be carried out over a period of time to ensure different system states and configurations are considered. The required scope of system states to be specified for services will be determined under WP1a monitoring in turn then defining the time period required for DSR and other distributed resource trials. Trials may require modification/ addition of control system of the DSR or other distributed resource service providers/ aggregators and confirmation of compatibility with SESG's platform.

The response delivered as part of the trial will be recorded and analysed to study the effectiveness, speed of delivery, availability, impact on the network, and any potential conflict with other services provided by the DSR aggregator.

Utilisation of Distribution (DNO-side) technologies

SESG will utilise a series of DNO-side technologies in the most appropriate manner to mitigate transmission operational challenges in each of the four distinct operational timeframes described above. The following DNO-side technologies are expected to be trialled in the SESG project:

- **Demand Side Response:** Demand side response aggregators will be able to provide a level of voltage support and MW response effect apparent the Transmission / Distribution system interface points.
- **Storage:** An embedded source of rapid response, again in voltage support and MW effect at the Transmission / Distribution system interface points.
- **Solar PV, embedded Wind and other distributed generation: in particular** SESG will investigate the possibility of dispatching solar generation (which is solely connected to DNO networks at present) and examine the effect from the dispatch of other distributed generation sources based on the requirements of the system operator.
- **Distribution Resources**: Resources available in distribution networks such as transformers with tap changers, transmission lines that may re-route power flows, modify voltage profile within the distribution system etc. can be made controlled to manage transmission system constraints.

In terms of the states described in section A5.2:

- States A and D are related to the long term usage of resources which would not be time critical but still necessary in order to maintain the system in an acceptable operating state according to planning and operational standards.
- States B & C, which are related to the stability response following a disturbance, will require the resources to act within a short timeframe. The role of DNO side technologies in these states would depend upon the latency in applying the service relative to the type of disturbance being experienced. Where the disturbances can be contained by distributed resources, the timeframes required will vary between 0-200ms (for dynamic stability and voltage support) to a number of seconds for voltage support. Recognising the different technologies have different timescales to respond, the objective of this project is to ensure

that a framework is developed so that all technologies contribute in an optimal manner.

Dependant upon the nature of the disturbance, DNO connected resources (both generation and demand side response) would be utilised to minimise the effect on the transmission system (managing the issues identified above) whilst ensuring that the effect upon the distribution system is managed.

The approach to SESG is to optimise the use of resources across timeframes A-B-C-D based on an approach which dispatches, based on the increased visibility of system state provided by monitoring, the appropriate service in the appropriate timeframe which provides the most overall technical and efficient outcome.

A5.4 Siemens' Solution Overview

Figure A5-4 below shows Siemens' Technical Solution detailing the necessary interfaces to ensure data exchange between systems contributing to the functionality of SESG. Spectrum Power and necessary links and monitoring equipment will be physically installed at locations which are identified and will be confirmed as part of WP1a. The proposed locations to extract information using the monitoring system (PMUs) are some of the GSPs identified and shown in Figure 2-5 (Section 2.2). The extent to which the monitoring will take place within distribution network (below GSPs) are dependent on the WP1a.

The monitoring and control centre will make use of one of the existing National Grid's data centres' building in Warwick/Wokingham and it will ensure sufficient access if given to the DNO partner. This will include access to the state estimator looking at "whole-system" and within the DNO's network.

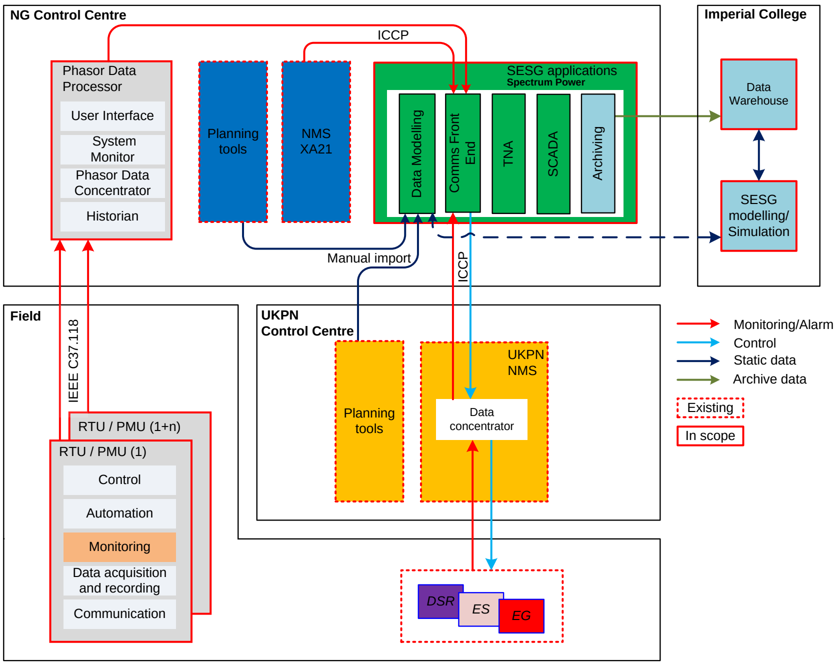


Figure A5-4 SESG Operational States

1. **Wide Area Monitoring**

Appendix 5: Technical Description Continued

a. RTU/PMU

The Siemens Siprotec Phasor Measurement Unit is an integral function found within the Siprotec 5 Intelligent Electronic Device suite of hardware. The hardware proposed for the SESG solution will be the Siprotec 5 Bay Control Unit (referred to as RTU/PMU on Figure A5-4).

Primary function of the Phasor Measurement Unit (PMU) is to monitor measurand values (Voltage and Current) at optimum positions on the Transmission network. The PMU samples sinusoidal input signals for Voltage and Current at 50Hz sample frequency with internal measures taken to provide anti-aliasing of the measured signal. The fundamental frequency component of the signal is removed and the resulting PMU output is an accurate phasor representation of that input (amplitude and phase angle). The sampled phasor is then time-stamped using a GPS receiver to establish a 'Syncro-phasor' which can then be aligned with other syncro-phasors from across the transmission network to give an accurate picture of system state at any moment in time. Table A5-2 below shows the comparison between Syncro-phasor measurement and conventional measurements taken from a protection relay / bay device:

Measured Value (conventional)	**Synchrophasor from PMU**
Slow to update (5 seconds typically)	Continuous update (100ms reporting rate typically)
No time stamp for the measured value	Every measurement time stamped at source
RMS values without phase angle	Phasor values of current and voltage (amplitude and phase angle)

Table A5-2 Comparison between Syncro-phasor and conventional measurements

This improvement in accuracy of measurement provides a clear benefit to the development and accuracy of a real-time Wide Area Monitoring (WAM) solution for analysis of system state within the SESG.

Optimum location for PMU's will be assessed during WP1A, though it is assumed the following eight transmission network nodes will be monitored as a minimum:

- Kemsley 400kV Substation
- Cleve Hill 400kV Substation
- Canterbury North 400kV Substation
- Sellindge 400kV Substation
- Dungeness 400kV Substation
- Ninfield 400kV Substation
- Bolney 400kV Substation
- Lovedean 400kV Substation

To secure the integrity of the WAM system, a minimum of two circuits will be monitored at each of these nodes to account for maintenance periods whereby a monitored circuit may be on outage.

Secondary functionality of the RTU/PMU device could be the local monitoring of transmission compensation resources such as Shunt / Series Reactors, Quad Boosters, MSC's, etc. It is not envisaged at this time that this functionality will be utilised as the proposed method of getting status of these resources will be via the communication link to the NGCC XA21 Network Management System.

b. Phasor Data Processor

Topology for a typical WAM using syncro-phasor measurements requires a central server which acts as the Phasor Data Processor (PDP). The high volume of data produced by the PMU's will be processed and stored in a central repository for arrangement and presentation to a third party system or user interface. Siemens software solution SIGUARD PDP, acts to provide the role of the PDP with Historian, WAM System Monitor, PDC and User Interface functionality. Communication to the PDP from PMU is via a Wide Area Network utilising the IEEE C37.118.2 communication standard over TCP. All data stored within the PDP can be easily accessed via a third party interface using ICCP or IEC 60870-5-104 protocol, or at the PDP user interface. The data can be used as an alternative to site fault records for post-event analysis to visualise the network response with respect to effects on Voltage Profile and Circuit Loading.

2. SESG Applications (Spectrum Power)

The SESG Applications System will be built on a Siemens Spectrum Power system which offers a suite of control and management applications from which those necessary to deploy the SESG method have been selected to apply as part of this solution. Within the suite, the applications are categorised into a number of functional areas, those relevant for SESG are described below.

a. Data Modelling/Information Model Management

The **Information Model Management** application will provide the ability to enter and maintain all related engineering data from NG transmission and UKPN distribution systems for use within Siemens Spectrum Power. These data will also be validated by evaluating with Imperial College's received data for their SESG simulation and modelling. The repository is based on the Common Information Model (CIM) as defined in IEC 61970 (EMS Application Program Interface). This application will be used to provide the SESG with the topological and electrical model data of both transmission and distribution systems to load the whole system electrical model into Spectrum Power.

b. SCADA

The SCADA application includes topology processing and visualisation. **Topology processing** ensures that the correct status and connectivity of all switches and plant is correctly reflected in the model used in the SESG control algorithms. **Visualisation** facilities for SESG engineering and operational purposes will also be provided by this application.

c. Archiving/Historical Information System (HIS)

The **HIS** will archive all SESG events, measurements and dynamic data received or produced by Siemens Spectrum Power. This data will be archived in a relational database and will be accessible for historical reporting and analysis. As an interface, included in this application are many of the functions that may be required by Imperial College for data warehousing purposes necessary for their validation and modelling.

d. Communications Front End (CFE)

The **CFE** application is capable of communicating using a wide variety of protocols and will be responsible for links with other parts of the SESG control system and the UKPN's Network Management System (NMS). It will enable various links to be used to receive all incoming measurements and plant data from the distribution network as well as to issue instructions based on transmission state.

Inter Control Centre Protocol (ICCP) is one of the communication links that will be used in real time to receive updates to network connectivity (monitoring) from National Grid and UK Power Networks (UKPN) NMS and also to send control requests to UKPN NMS. In the absence of ICCP link, other alternative communication routes can be utilised to access offline ("real time") network data.

e. Transmission Network Applications (TNA)

The transmission network applications are the principal components for delivering the required control functionality of the SESG.

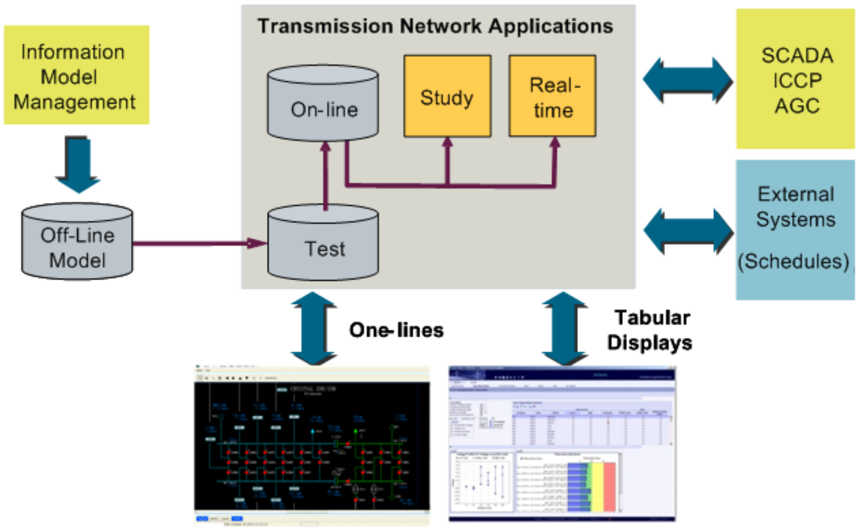


Figure A5-5 TNA Overview

TNA will provide the analytical tools required to perform operational planning and assess the reliability of SESG in real time. Siemens spectrum power will use this application to analyze further the potential for n-1 contingency limit violations or short-circuit fault limit violations, as well as power transfers and voltage stability limits within SESG. The TNA suite of applications is configured into 2 main packages (Analysis and Optimisation):

i. Transmission Grid Analysis Applications

The TNA package includes applications required to build base cases and perform static security analysis. SESG will utilize relevant applications within the TNA suite such as:

- Dispatcher Power Flow (DPF)
- State Estimator (SE)
- Network Parameter Adaptation (NPA)
- Contingency Analysis (CA)
- Security Analysis (SA)

- Outage Scheduler (OS)
- Security Analysis Look-Ahead (SL)
- Voltage Stability Analysis (VSA)
- Short Circuit Calculations (FC)
- Network Sensitivity (NS)
- Transmission Capacity Monitor (TCM)

The Transmission Grid Analysis package will be used to create base cases in real-time and study modes. These cases will form the basis for further analysis by other network applications such as Security Analysis, Voltage Stability Analysis, Transmission Capacity Monitor and Short Circuit Calculations. Real-time cases are built using the State Estimator while study cases are created from the DPF. A data collection function will process the network topology for use as input to DPF and SE.

The Outage Scheduler will maintain a record of expected future generation and equipment outages and optional specification of generator operating MW and operating limits. In study mode, active (with respect to the study day and hour) outages are retrieved and included in the base case.

Balanced and unbalanced fault analysis can be performed with the Short Circuit Calculations application. Network Sensitivity computes real-time loss sensitivities. Voltage Stability Analysis will determine the system margin to voltage collapse. Transmission Capacity Margin will calculate the amount of additional power that can be transferred through designated SESG transmission lines and transmission corridors.

ii. Transmission Grid Optimization Applications

The Optimization package includes applications that will be used to optimize SESG system operation and this comprise of:

- Optimal Power Flow (OPF)
- Voltage Scheduler (VS)
- Security Dispatch (SD)

The Optimization package will use cases from the Transmission Grid Analysis package to perform studies of how to utilize the SESG better. The **Optimal Power Flow** can be used in study mode to provide suggested control settings for optimal system operation of SESG. The Security Constrained OPF option can be implemented if contingencies are required to be considered as constraints to provide corrective and preventive control strategies.

In real-time mode, the **Voltage Scheduler** will suggest control settings to eliminate reactive power and voltage limit violations and minimize losses. **Security Dispatch** will optimize operations by suggesting controls that eliminate active power violations at minimum cost.

3. Siemens' Scope of Works

Siemens' principal role is technology supply and solution delivery associated with WP1B – it is considered that Siemens will have involvement with WP1C, i.e. co-ordinated control between the TO and DNO, in at least a support capacity, this will be determined based upon the outputs from WP1A and WP1B, along with discussions with UKPN, to inform the optimal methods of enacting control of distributed resources.

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 5: Technical Description Continued

Siemens has worked closely with Imperial College and National Grid in developing the phasing and dependencies of related work packages in the Project Plan (Appendix 3). The activities of Imperial College and Siemens will be closely coupled during the delivery of WP1A and WP1B (refer figure A5-4) to ensure that the modelling, design and trial data requirements are fully aligned, this will include regular review meetings between National Grid, Imperial College and Siemens.

Below is a summary of the work that Siemens will be carrying out as part of SESG under each of the work packages:

<u>WP1A – Development of Tools and Techniques for Whole System Evaluation of Smart Solutions</u>

- Support high level design concept with Imperial College on proposed whole system modelling / monitoring of transmission and distribution network
- Siemens will provide a detailed description of Spectrum product and Transmission Network Applications (TNA) to support design of trials and co-ordinated control strategies

<u>WP1B – Wide Area Monitoring across South East (T&D State Estimator)</u>

- Validate and refine system design concept (Figure A5-4) based upon output of WP1A
- Detailed design and specification of interfaces for SESG
- Procurement, Design, Configuration and Factory Acceptance Testing of SESG Application Platform (Spectrum) and Monitoring System (Phasor Measurement Units) for South East network
- Installation of Monitoring Systems at 8 Transmission Substations, plus any additional monitoring (as identified during WP1A) for transmission and distribution network resources
- Installation of SESG Application Platform within National Grid Control Room and establish interfaces with legacy TO and DNO systems (Figure A5-4)
- Site Acceptance Test and commissioning of SESG system
- Support trials and analysis/dissemination of results from WP1B

<u>WP1C – Co-ordinated Control of Transmission and Distribution Resources</u>

- Support National Grid and UKPN with Solution development for co-ordinated control of distribution resources and interface requirements to SESG Application Platform
- Support trials and analysis/dissemination of results from WP1C

<u>Knowledge Dissemination</u>

- Siemens will support National Grid and other project stakeholders in Learning and Dissemination of SESG knowledge, through a range of events, such as workshops, webinars and conferences, including the annual LCNI conference

Appendix 5: Technical Description Continued

A5.5 Proposed Program of Works for Imperial College

In order to accomplish the solution described in A5.4, Imperial College will be providing an invaluable academic contribution which has been broken down here into the contribution for each work package (WP):

WP1A – Development of Tools and Techniques for Whole System Evaluation of Smart Solutions

T1.1: Development of simulation models of the South East network

Imperial will develop dynamic model of the South East system covering both transmission and distribution networks. Models of the asynchronous components (e.g. interconnectors, wind farms, PV etc.) would be integrated to the South-East network model. Alternative aggregated distribution network models will be investigated (as discussed in T1.3) to capture distributed energy resources (DERs) and local network constraints. In any case, the South East network will be modelled to the level of detail required for the SESG project. Modelling transmission and distribution systems in total detail would not prove practical but Imperial College will ensure that sufficient level of detail is captured for the project.

Neighbouring areas surrounding the South East Network would be represented by reduced equivalents which would be validated against the detailed model in terms of boundary flows etc. The model especially, the aggregated representation of the DERs would be refined, as necessary throughout the project based on the updated information available from the field trials.

T1.2: Identification of optimal locations for installing monitoring devices

While National Grid has already identified the 8 minimum locations of monitoring, as presented in section A5.4 1-a, it must be noted that this is the minimum identified and through Task 1.2, Imperial College will be able to identify whether further monitors would be suitable. The additional monitors would help would help support our understanding of the effect that these distributed resources have on the transmission system when providing a service and address any requirements in the compliance and capability of the service itself at source.

Identifying the appropriate number and locations for installing the monitoring devices (e.g. phasor measurement units) is essential for real-time monitoring of the system states, stability margin assessment and also determining the set of preventive and corrective control actions. The key objective of this activity will be to select a set of such locations within the South East network that will offer robust and global observability and specifically, allow accurate estimation of the voltage stability margin (VSM). Optimal number and location of monitoring devices would be based on extensive simulation studies (using the models developed under T1.1) under a wide range of operating scenarios. The monitoring device placement problem would be posed as an optimisation task of determining the total number of devices considering the measurement redundancy while ensuring total observability of the South East network.

Optimal placement of PMUs and estimation of VSM will strongly depend on the characteristics of the control resources available both at the transmission and distribution level, on their specific locations and on also the control philosophy adopted (covered in WP1C). Hence the design of system level monitoring and state estimation architecture will be informed by the characteristics of the individual control resources at transmission and distribution levels and how those are coordinated (WP1C). These inter-dependencies have not been previously studied and will involve iteration process across the work packages.

T1.3: Development of Virtual Power Plant concepts to enable flexible resources in distribution networks to support control of the South East transmission network

The models developed in T1.1 will then be used to develop Virtual Power Plant concepts that would aggregate Distributed Energy Resources (DER) into a single, controllable virtual unit replicating the aggregated control effect in order to maximise modelling efficiency. These resources, which include demand side response, various forms of distributed generation and energy storage, may provide a significant flexibility to support the operation of the South East transmission network. In this context, Imperial College would enhance the existing advanced Technical Virtual Power Plant (TVPP) modelling concepts with the objective to develop aggregated dynamic models of the DER which could be incorporated with the South-East network model. For the aggregation of individual dynamic models with different characteristics and response times model estimation techniques would be used to match the dynamic response under a range of operating scenarios. Regarding the demand response based DER, appropriate load recovery patterns will be developed for the characterisation of VPP. These models would be validated and/or recalibrated using data from field trials conducted with UK Power Networks (UKPN). This would provide the necessary assurance to the system operator that the DER will be able to support transmission network whilst respecting the distribution network operating constraints and limits. The next stage is to examine the extent to which the flexibility embedded within the distribution networks can be used to provide network services such as reactive power, voltage control, and various forms of reserves at the point of connection between transmission and distribution.

In addition to the Technical VPP, this work will also include development of Commercial VPP (CVPP) to include costs associated with DER commercial contracts. In this instance, the CVPP will provide commercial visibility of DER capacity to the system operator while offering various transmission system balancing and ancillary services. This will enhance the interface between UKPN / National Grid and enable, for the first time, development of a whole-system approach to cost-effectively integrate and actively control DER in support of operation of both distribution and transmission networks.

T1.4: Investigation of coordinated control strategies in collaboration with Siemens and validation of the control platform through computer simulation

With multiple flexible technologies and resources available at the transmission (VSC-HVDC interconnectors) and distribution (DER) levels, their action will need to be coordinated to deliver the optimal aggregated response. The coordinated control algorithm should optimise the level of preventive and corrective response of each of the flexible resources, taking into account their location, steady-state, dynamic capabilities and cost of associated contracts. As some of the actions may impact pre and post fault active power schedules, through adjusting the flows on interconnection, the optimal portfolio of preventive and corrective actions will need to minimise the cost of system operation. For this purpose, Imperial College would enhance their advanced Security Constrained Optimal Power Flow (SCOPF) models and incorporate dynamic constraints through implementing novel system reduction techniques recently developed by them.

For implementing coordinated corrective control of the multiple resources in real time, Imperial College would use advanced Model Predictive Control (MPC) framework. This would for example, employ the voltage measurements (available through PMUs) as feedback and determine the active and/or reactive power reference settings of VSC HVDC interconnectors, and DERs in order to regulate the voltages along the Kemsley-Lovedean 400 kV corridor within acceptable limits. As the operating condition would vary frequently between extremes (e.g. high interconnector export to high import situations) non-linear MPC approaches could be used. Furthermore, there are important practical considerations, which may demand a hierarchical control response. For example, in case of a voltage support problem, ramping up the reactive power supply from a VSC-HVDC converter should be exercised and exhausted first before reducing the active power export which could be associated with high costs. Such a hierarchical scheme could be embedded within the MPC framework.

T1.5: Extend the existing real-time network simulation platform to simulate the behaviour of the South East network in real time

To supplement the computer simulations, real-time hardware-in-loop (HIL) simulation will be carried out at the Maurice Hancock Smart Energy Laboratory at Imperial College. The dynamic behaviour of the South-East network will be emulated in real-time. Imperial College has got an Opal-RT simulator which can emulate the dynamic behaviour of relatively simple networks in real time. The capacity of the simulator would have to be upgraded through modular addition of processors to enable real-time simulation of the whole South East network. Computer simulation models built in Matlab/SIMULINK could be directly loaded onto real-time target. However, for other platforms (e.g. DIgSILENT PowerFactory), the interface issues would have to be resolved

T1.6: Integrate the physical hardware (converters for interconnectors, aggregated storage etc.) with the real-time network simulator to create a hardware-in-loop simulation environment

Computer simulation models of the South East transmission network including the conventional generators etc. and the distribution network (down to a certain level from the GSPs) would be developed at Imperial under T1.1. These models would then be rebuilt in a format that is compatible with the real-time target of Opal-RT. Computer simulation models of the network built in Matlab/SIMULINK could be directly loaded onto real-time target. However, for other platforms (e.g. DIgSILENT PowerFactory), the interface issues would have to be resolved first. The existing real-time simulation facility at Imperial would have to be upgraded to handle the whole South East network.

The real-time network simulator (Opal-RT) would be integrated with scaled physical models of relevant elements of the South-East system, specifically the VSC- HVDC converters, to build a hardware-in-loop setup.

The SESG project aims to exploit the capabilities of the distributed energy resources (DERs) to provide support in managing constraints in the South East transmission network. Such exchange of service provision across the distribution/ transmission interface is predicted on advanced monitoring, state estimation and control. The service providers i.e. the DERs, may be interfaced with the network through power electronic converters for which 'simple yet representative' models for system level studies are yet to be standardised. With no prior operating experience, computer simulations alone would not provide the necessary confidence needed to carry out field trials. As an intermediate step, hardware-in-loop testing with the transmission and distribution system modelled in a real-time simulator (e.g. Opal-RT) which is connected to the physical power converters mimicking the behaviour (scaled version) of aggregated DERs is likely to reveal possible interactions in the relevant time scales which the computer modelling would not necessarily reveal.

The same argument applies to testing control of multiple HVDC via hardware-in-loop: there maybe factors un-modelled in a simulation that are uncovered in hardware and there is an opportunity to verify that the control algorithm can execute in real-time.

The interface between the Opal-RT and the physical hardware would be a power converter acting as a power amplifier as shown in Figure A5-6.

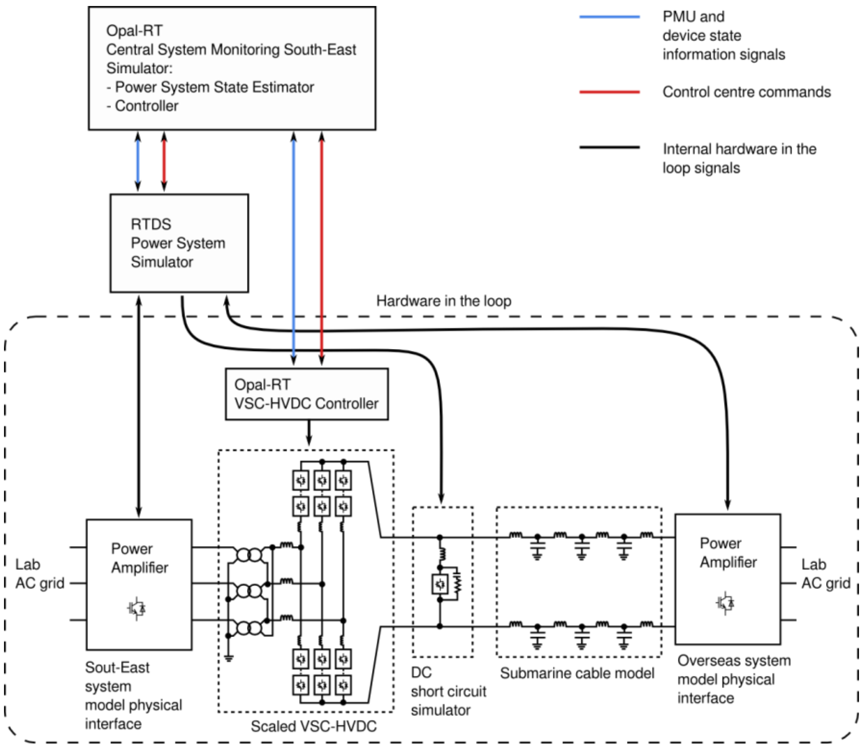


Figure A5-6 Setup that would be used for the real-time demonstration at the Maurice Hancock Smart Energy Lab (Imperial College)

The real-time hardware-in-loop set-up will virtually emulate the dynamic behaviour of the South East network including the transmission and distribution level resources. Thus this would be platform for validating and testing the coordinated control strategies before attempting filed trials.

T1.7: Validate coordinated control strategies with real-time hardware-in-loop simulation

The real-time hardware-in-loop simulator (developed under T1.6 and T1.7) would provide a test bench for validating the coordinated control strategies. A motivation behind real-time simulation is to verify that the complex control algorithms (such as model predictive control) can be computed on realistic hardware within each sampling interval (with no 'calculation overrun') and communicated to the DERs. This should provide evidence that the real-time operation of complex control scheme is feasible. This would supplement the validation exercise through computer simulation (T1.4) and provide the necessary confidence for going ahead with field trials. The real-time control strategies developed in this project will be implemented in a rapid control prototyping (RCP) platform from Opal-RT. The control hardware will receive measurement signals from a real-time network simulation platform and issue control commands back to it the same way as the Central System Monitoring-South East would do. The interface between the real-time HIL simulation setup and the RCP would be in analogue domain. So each side would virtually mimic a scaled down version of the actual situation in practice.

Hardware-in-loop testing methods

Computer simulation models of the South East transmission network including the conventional generators etc. and the distribution network (down to a certain level from the GSPs) would be developed at Imperial under WP1A. These models would then be rebuilt in a format that is compatible with the real-time target of Opal-RT. Computer simulation models of the network built in Matlab/SIMULINK could be directly loaded onto real-time target. However, for other platforms (e.g. DIgSILENT PowerFactory), the interface issues would have to be resolved first. The existing real-time simulation facility at Imperial would have to be upgraded to handle the whole South East network.

Imperial has over the last two years constructed scale-model VSC HVDC converters (of multi-level format) controlled by Opal-RT platforms and has a physical representation of a 4-terminal DC cable networks. It has previous experience of using Opal-RT for real-time modelling of AC networks. To this will be added power amplifiers that take voltage signals from the real-time simulator and create AC voltages to apply to the VSC hardware. Thus the combined AC network and DC network can be physically represented in real-time. The controllers of HVDC will be fully represented (albeit scaled-down) without any simplification (such as neglecting switching effects) and can be run for many minutes or hours. This is a fuller and more realistic test than can be achieved in computer simulation. The hardware can test dynamic response and fault conditions.

Testing of DER within the SE transmission network will make use of the programmable converters and AC distribution network impedances available at the Smart Energy Lab at Imperial and connect these to the power amplifiers that replicate the voltages from the real-time simulation of the transmission network. Again dynamic responses of the closed-loop controllers will be tested.

WP1B – Wide Area Monitoring across South East (T&D State Estimator)

Imperial analysis and simulation studies (under WP1A) will inform WP1B by identifying most appropriate sites for monitoring.

WP1C – Coordinated Control of Transmission and Distribution Resources

Imperial College will support validation of the coordinated control schemes using the real-time test facility (described under WP1A). For the interconnectors, offshore wind farms and aggregated storage, scaled-down physical hardware set-ups would be used in the validation exercise. Other resources would be included within the network model running on an Opal-RT simulator. The coordinated control strategies would be implemented within a rapid control prototyping control (RCP) platform from Opal-RT with an analogue interface between the system emulation and RCP platforms.

WP2 Development of Commercial Tools and Services

T2.1: Development of novel commercial contracts for SESG

In collaboration with Elexon, Imperial College will carry out analysis of alternative forms of commercial contracts with DER embedded in UKPN system, for the provision of generation-led and demand-led response ancillary services to the South East transmission system. This will require coordination between Transmission and Distribution network operators to ensure that that the DER offering services will be able to support transmission network whilst respecting the distribution network operating constraints and limits. In this context, Imperial will develop models for the analysis of the conflicts and synergies associated with provision of multiple services by DER, from both system and service provider perspective.

This Task will further investigate the principles for setting up the contractual arrangements that may accompany delivery DER services to transmission system operator. This will include consideration of contracts that include option and exercise fees and alternative forms of penalties for non-delivery. The impact of duration of contract will be considered.

Imperial will also develop alternative approaches and models for characterising the performance of DER based services using actual information form the trials. This will be then used to inform the need for redundancy in portfolio of service contracts that the system operator may need, in order to optimise network reliability performance given that some DER service delivery may be characterised by reduced availabilities. This will include evaluation of corresponding cost implications and provide input to the Cost Benefits analysis. This will be critical for assessing the technical and commercial viability of non-build solutions concepts in supporting future transmission system operation and displacing conventional transmission network reinforcements.

T2.2: Option value of SESG contracts

There is significant uncertainty associated with future development of South East network. It is expected that a very significant amount of PV generation may be deployed within the UKPN network in coming decade. Furthermore, offshore wind generation in the area of London Array, Greater Gabbard and Thanet may be further developed. This may be accompanied with load growth and in the longer term with electrification of transport and heat sectors.

As the spatial and temporal properties of both demand and generation in the future, are characterised by a significant degree of uncertainty, DER may provide flexibility and make the future network reinforcement more certain and hence cost effective in the long run. In this context, Imperial will develop stochastic optimisation models that will reveal the option value of DER based contracts, through quantifying the reinforcement cost savings by postponing investment decisions and gaining more accurate information regarding uncertain changes in the network, as well as the economic value at risk of DER contracts (CVaR), revealing the incurred reinforcement costs in worst-case conditions. This will involve development of least-regret decision analysis designed to identify a robust portfolio of contracts to deal with uncertainty in timing and amount of future generation, demand and interconnection deployment.

WP3 Need Case Development for Rollout to Other Areas

In order to support the roll out of advanced control solutions trialled, it will be critical to fully understand the risks associated with SESG paradigm. Imperial team will carry out in depth analysis and evaluate the consequences of failures of corrective actions, identification and handling of inaccuracies and delays in real-time measurements and assessment of the overall robustness of alternative designs and control strategies across a range of system operating conditions (Task 3.1). Moreover, Imperial College will support wider roll out by carrying out comprehensive analysis in other areas of the Great Britain transmission network to investigate the technical and economic benefits of applying control strategies developed and tested (WP1B and WP1C) in SESG project (Task T3.2).

T3.1: Risk analysis of SESG non-build solutions

Application of smart grid technologies and advanced coordinated control to enhance the performance of the South-East network comprises a shift from a traditional preventive approach to security to one that is increasingly dependent on just-in-time corrective actions, including contribution form a range of DER embedded in distribution network. It is therefore critical to fully understand the risks associated with the smart grid paradigm and Imperial team will carry out novel modelling and analysis to quantify the risk profile associated with the application of alternative control strategies developed in the above tasks. In particular this analysis will involve:

- Evaluation of consequences of failure of corrective actions and associated risk profile
- Identification and handling of inaccuracies and delays in real-time measurements that are used to make control decisions and quantifying corresponding risk exposure to further outages
- Assessment of the overall robustness of alternative designs and control strategies across a range of operating conditions of South-East Smart Grid

In this context, Imperial team will apply their novel probabilistic risk assessment models considering all candidate solutions to inform the development of SESG and wider roll by assessing and deriving robust corrective control strategies to minimise the risk exposure to rolling outages.

T3.2: Rolling out SESG paradigm to other areas of the GB system

Imperial will carry out extensive computer simulation studies to investigate the effectiveness of advanced monitoring and coordinated control across the transmission and distribution boundary in other parts of the GB system. To this end, the coordinated control strategies will be enhanced and generalised as appropriate. This work will involve expanding on Tasks T1.1-T1.4 for other parts of the GB network with the required adjustments to suit different network characteristics and operating regimes and future development. This will also include analysis of the appropriateness of developed SESG novel commercial arrangements.

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 5: Technical Description Continued

A5.6 Potential for Rollout to other areas

Gone Green scenario anticipates a considerable growth in distributed generation resources across the whole of GB as illustrated in the graph below.

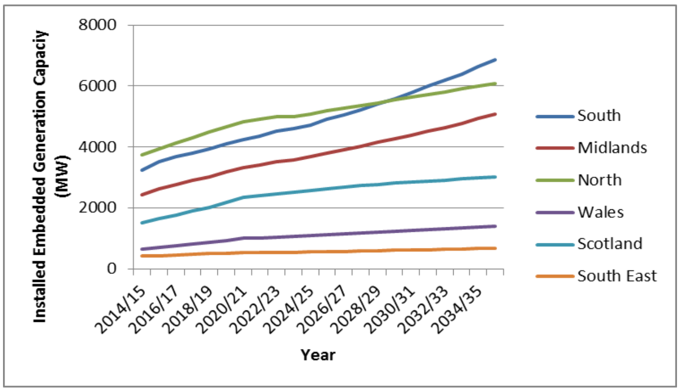


Figure A5-7 Installed Capacity of Embedded Generation at different regions (Gone Green)

Northern England in particular is expected to see even higher rate of growth of distributed resources than the South of England and also face similar challenges in the future due to new HVDC connections post 2020 (links to Norway and large Round 3 offshore wind farm connections on the East Coast) therefore SESG is considered to be applicable and replicable across the GB.

With regard to the minimum service which can be expected from the distributed resources, it very much depends on the type, and load factor of the embedded generation. The graph below shows the output (production) of the embedded generation at summer minimum conditions (when the demand is at the lowest). It highlights the potential volume of service which can be expected from the embedded generation at this time.

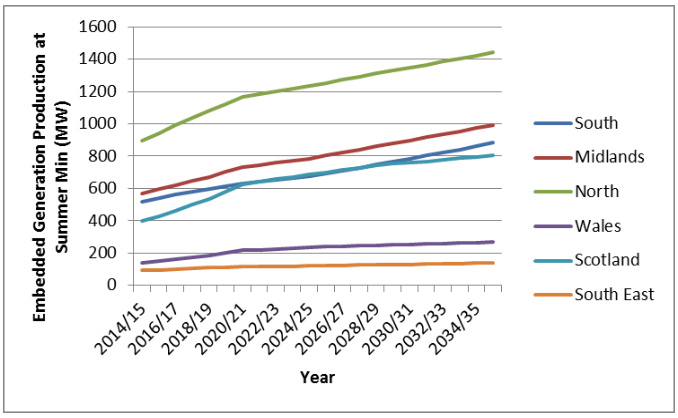


Figure A5-8 Embedded Output at different regions(Gone Green)

RIIO NIC NETWORK INNOVATION COMPETITION

Project Code/Version No: NGETEN02/V2

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 6: Cost Benefit Analysis

This section provides a detailed analysis of the benefits of the SESG project.

A6.1 Background

A recent report published by National Grid Interconnectors[1] suggested that meeting the European Commission's target of having at least 10% of the installed capacity through European interconnection could save the GB consumer up to **£1 billion per year** by 2020 thanks to the import of low cost, low carbon energy from mainland Europe. This 10% installed capacity would be the equivalent of installing an additional 4-5GW of interconnectors by 2020 and it is National Grid's responsibility to ensure that these interconnectors can transfer power without constraint, while ensuring the most economic and efficient solution to achieve this.

In the South East, National Grid's Future Energy Scenarios estimate that 2GW of European interconnectors will connect by 2020. This is half of the required interconnection capacity to meet the 10% target stated above. Therefore, it can be assumed that half of the savings would result from the interconnectors in the South East, i.e.: **£500m annual saving to the GB consumer**. However, this saving would only be possible if the interconnectors have unconstrained operation, which is currently not possible due to the technical challenges in the South East area, as detailed in section A6.2.

A6.2 Business as Usual

National Grid plans the GB transmission system consistent with the requirements of Chapter 6 of the NETS SQSS[2] both in respect of the steady state and dynamic management of voltage disturbance such that no instability, scale of disturbance or planned operation outside of voltage regulation limits occurs. As detailed in Appendix 5, the South East network has a series of technical challenges which may result in falling outside of these planning limits, requiring constraining generation (including interconnectors) or triggering further network reinforcements. The following is a list of these technical challenges, with their associated "Business as Usual" (BaU) cost estimates:

1. **Steady State Voltage:** During periods of low demand (i.e. when the interconnectors in the area are floating), the long transmission lines in the South East become lightly loaded, resulting in high voltages that need to be managed. The BaU approach to manage this challenge is to constrain generation in order to maintain the voltage within operational limits as well as contracting generators to provide reactive power support. A review[3] of the historical utilisation of reactive power in the South East area concluded that the current costs are in the range of **£14m per annum**.

Cost: £14m/annum

[1] Getting More Interconnected, March 2014. Available at: http://www2.nationalgrid.com/About-us/European-business-development/Interconnectors/

[2] NETS Security and Quality of Supply Standard Available at: http://www2.nationalgrid.com/UK/Industry-information/Electricity-codes/SQSS/The-SQSS/

[3] Based on information from: http://www2.nationalgrid.com/UK/Services/Balancing-services/Reactive-power-services/Enhanced-Reactive-Power-Services/ERPS-Information/

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 6: Cost Benefit Analysis Continued

2. **Dynamic Voltage Stability:** This is a current challenge in the South East area which happens in particular at high transfer periods of interconnectors, caused by the long transmission lines and the absence of voltage control equipment. As the level of European interconnection increases, the problem is exacerbated and more reactive compensation equipment will be necessary. National Grid has carried out in depth dynamic voltage analysis taking into account the technical specification of the new HVDC interconnectors that would in the South East area. This analysis has revealed that at the time of the first 1000MW of additional interconnector connection, even with particular new technical specification of the interconnectors' performance in this scenario, a further **675 MVar** of dynamic reactive power support is required. This would be achieved by installing 3x225MVar dynamic units. Based on previous projects, a very conservative figure of £20m per unit of compensation will be considered. Therefore, the BaU cost would be of £60m (3x£20m).

   Cost: **£60m capital investment**

3. **Commutation of CSC-HVDC:** CSC-HVDC is the convertor technology that is used in the existing interconnectors in the South East area. With this technology, there is a risk of commutation failure which would result in the interconnector being disconnected from the system with an unacceptable impact to the system. This risk is typically managed by constraining the operation of these interconnectors in periods of low system strength. Currently in the South East, there are two 1GW links using the CSC-HVDC technology. The constraint solution requires them to be de-loaded to 500MW each to mitigate the risk of commutation failure. I.e. a total of **1GW** (1000MW) of interconnectors will be constrained. For each MWh of reconciliation between constrained and unconstrained runs will be valued at a benchmark value (currently estimated at £70/MWh; which is the SO to SO trade value). In addition, an extra cost is incurred to due having to procure the energy which could have otherwise been provided by the import of energy from the interconnector. This is assumed to incur additional £80/MWh (1.6 times of a cheap gen set). Therefore, the value of **£150/MWh** (£70/MWh + £80/MWh) will be used for this calculation.

   Our analysis has shown that in the future, with the closure of conventional power stations, the system strength in the South East will fall below the minimum level which is required to enable the operation of the links at full capacity in import mode. The analysis showed that this is estimated to happen between 12-18% of the time in a full year's operation. Taking a conservative figure of only 12% (as it can be expected to rise to 18%) of time, and assuming interconnectors are in import mode (the mode requiring constraint) only half of this time (i.e. **6% of time**), the annual cost can be calculated:

   $$1000 \text{ MW} * 8760 \text{ h/year} * £150/\text{MWh} * 6\% = £78.84\text{m/year} \approx £80\text{m/annum}$$

   Cost: **~£80m/annum**

4. **Thermal Overloading and Rotor Angle Stability:** With the increasing amount of installed capacity in the South East area, in particular European Interconnectors, there will be the inevitable requirement to build a new transmission route in order to maintain security of supply. This requirement was identified in National Grid's Electricity Ten Year Statement 2013 (ETYS) Chapter 4, which states that under the Gone Green Scenario, a new transmission route in the South Coast will need to be built by 2023 in the area shown in Figure A6-1. The need for new transmission

capacity arises from voltage, thermal and stability considerations in particular when the South East Loop is severed such that its connections to either Kemsley in the north or Lovedean in the west are lost. From detailed transmission studies, under business as usual, it was determined that a new transmission route represented the most economic and efficient reinforcement to the current interconnector connections, following the connection of the first 1000MW project. The current estimate for this new route is approximately £500m.

Cost: Circa £500m capital investment

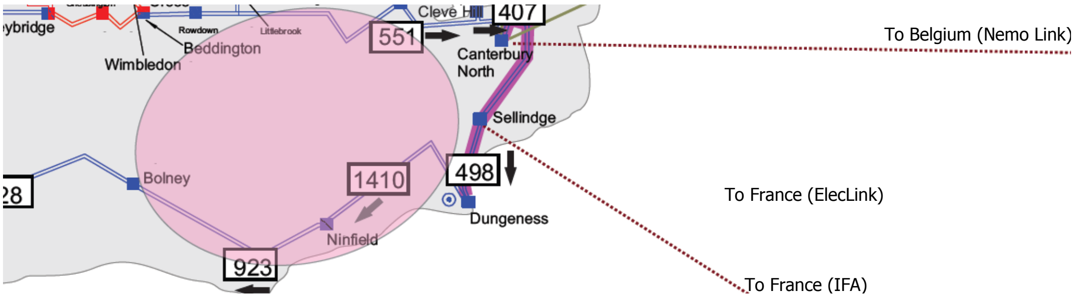


Figure A6-1 Area for new transmission route in South East. Source: ETYS 2013

A6.3 Effect of SESG

SESG will provide savings by solving each of the technical challenges described above in a different way to 'business as usual':

1. **Steady State Voltage:** SESG will use innovative techniques, such as Demand Side Response (DSR), to control the power flows in the South East area in order to remove the requirement to constrain generation for managing high voltage issues in the South East Area. Note, however, that there will still be certain areas around London which have existing high voltage issues and these areas will not be covered by the scope of SESG. It is expected that there will still be a cost for managing those high voltage constraints at an estimated £8m/annum. Hence, the saving from SESG would be £6m/annum compared to the 'Business as Usual' approach.

Saving: £6m/annum

2. **Dynamic Voltage Stability:** SESG seeks to present a "whole network" perspective to transmission system management in identifying such opportunities to offset transmission investment. Based on the methods described in the main submission document, in particular WP1B and WP1C, as well as taking into consideration of the potential volume of service providers locally, we concluded that the SESG has the initial ability to provide between 150-200 MVar equivalent controllable reactive compensation at the transmission level and therefore this capability can be used as an alternative to building a new reactive power compensation. From this, it can be assumed that SESG will remove the need for at least one unit (225MVAr) of reactive compensation equipment, resulting in a saving of £20m, based on the conservative assumption considered in section A6.2.

Saving: £20m avoided investment

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 6: Cost Benefit Analysis Continued

3. **Commutation of CSC-HVDC:** SESG will provide greater visibility over how the network performs and will enable the analysis of voltage disturbances as well as taking action to minimise the impact of these. SESG will also enable better outage coordination and better impact assessment of the outages which could bring the short circuit level at Sellindge 400kV below the level which the link can operate in full import mode. It is expected that thanks to SESG, interconnectors will only need to be constrained about half of the time (between 45%-55% of the time), resulting in a saving between £35-45m/annum as a result of the need for constraining the link.

Saving: **£35-45m/annum**

4. **Thermal Overloading and Rotor Angle Stability:** The SESG project has the potential of avoiding the new build identified in section A6.2 by actively managing power flows in the area and using the existing equipment more effectively. This benefit is reliant on the ability under SESG at a more granular level to combine actual outputs of generators/ interconnectors in the area, the behaviour of the latent demand profile and in the nature and volume of distributed services that might ultimately be made available to the system to affect the characteristics of the demand interface in ultimately removing the current effect of the last up to 1000MW of additional interconnector impact dynamically and in the steady state that would otherwise drive further network reinforcement and a period of network restriction management ahead of that reinforcement. The role of SESG will be to determine the volume of management options against the time periods of their requirement to sufficient detail that would allow all options available to the existing network to mitigate future capacity to be explored ahead of further new route requirements being developed. The potential of this innovative approach will be the avoided capital investment of a new transmission route in the South East, which, as stated in section A6.2, would have cost approximately £500m.

Saving: **Circa £500m**

In addition to these savings, SESG will bring a wider saving to the GB consumer by enabling a £500m/annum benefit from the operation of unconstrained European Interconnectors.

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 6: Cost Benefit Analysis Continued

A6.4 Summary

The following table summarises the key points from this analysis:

Network Characteristic	How affected in the South East region	Consequence	Impact on Cost	How SESG Helps
Steady state Voltage	Low demand (when interconnectors are floating), long transmission lines (high charging gain)	Significant constraint cost to control voltage	In excess of **£14m** just in 2013 and will inevitably rise	No longer requires constraining generators => **£6m** savings per annum
Dynamic Voltage Stability	Long transmission lines, absence of voltage control plants (power station, FACTS) particularly at high transfer periods of interconnectors	With increasing the level of interconnectors the problem is exacerbated – Need for extra reactive power compensation	At least **£60m** extra investment once new interconnectors are connected (based on £20m unit cost for a 200MVar Statcom x3)	At least **£20m** savings by removing the need case at least one unit
Commutation of CSC-HVDC	Reduction in network strength (short circuit level) when large power stations are not running	Constraining the HVDC Interconnectors flow (**import capability**) and risk to **Security of Supply-** as a result of permanent shut down of the link	In excess of **£80m per annum** based on just 6% of time, and import restriction of 1000MW (500 MW on each bipole)	Allow unrestricted flow by providing a coordinated response (small disturbances will have less impact on commutation) – The savings are at least for half of that time (between **£35m-£45m per annum**)
Thermal overloading and Rotor Angle Stability	Following a transmission fault the loading level on the remaining circuits will be high and significant phase shift increase	Requirement for building a new transmission line	**circa £500m**	Defers/delays the need case

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 7: Organogram of the Project and Description of Partners

This Appendix provides more information of the partners of the project and their relation to the project.

A7.1 Organogram

Figure A7-1 below shows a high level organogram of the SESG project.

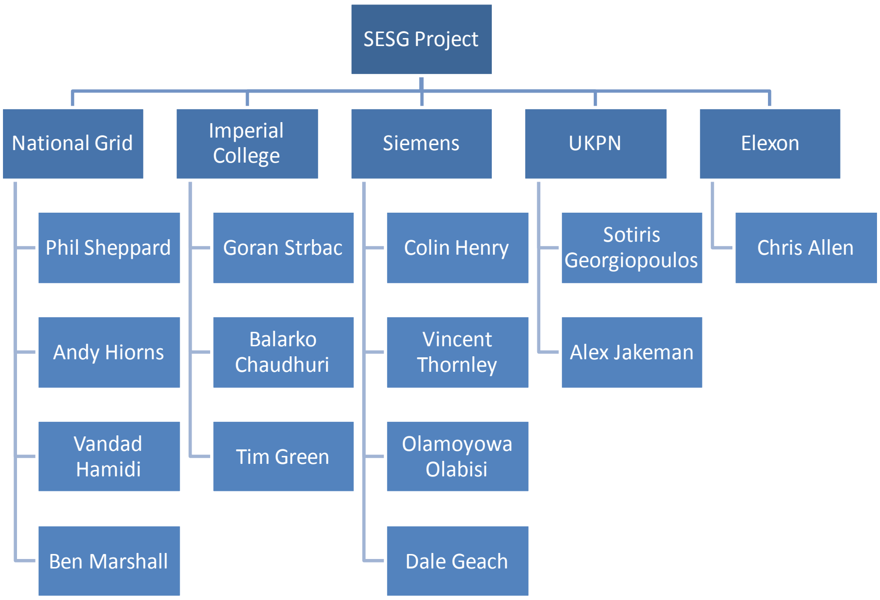


Figure A7-1 SESG High Level Organogram

A7.2 Members of the team

The following section provides a short description of all the people involved in the SESG project.

nationalgrid

Dr. Richard Smith *(Head of Network Strategy)*

Dr. Richard Smith is Head of Network Strategy, accountable for ensuring the long operability of the Gas and Electricity Transmission Networks. This includes identifying the need for future transmission reinforcements to meet capacity requirements under a range of scenarios, the changing characteristics of supply and demand, potential regulatory and commercial options and that the delivered solutions are co-ordinated, economic and efficient. Prior to this role, Richard was the Head of Energy Strategy and Policy, and accountable for development of Future Energy Scenarios (FES), supporting and developing energy policy, ensuring that National Grid plays a pivotal role in enabling the UK Government to meet its 2020 renewable targets and 2050 carbon emission targets.

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 7: Organogram of the Project and Description of Partners Continued

Andrew Hiorns *(Electricity Network Development Manager)*

Andy Hiorns is Electricity Network Development Manager responsible for developing vision and direction for future electricity networks in National Grid. He has over 40 years of experience in the electricity industry and brings an in depth knowledge of power system. In his most recent role, he was the project director of Western HVDC project resulting in the most pioneering solution developed for design of a new 2.2GW link between Scotland to England. Andy has led the development of Network Development Policy (NDP) ensuring the most economic and efficient solutions for network investment.

Dr. Vandad Hamidi *(SMARTer System Performance Manager)*

Dr. Vandad Hamidi is the SMARTer System Performance Manager responsible for developing the advanced, tools and techniques enabling the most economic and efficient design and operation of the electricity transmission system. He received a Ph.D in power systems and was awarded the Royal Academy of Engineering (RAEng) prize for his project on Demand Side Response in 2008. He has extensive experience of control system design, and power system modelling and has managed number of front-end onshore and offshore electrical system design projects in Europe and North America. In his current role, he has developed National Grid's System Operability Framework (SOF); ensuring future operability of the GB transmission system, and represents National Grid in Smart Grid Forum.

Ben Marshall *(Technical Specialist)*

Ben Marshall is a Technical Specialist in Power System Analysis, specialising in areas of dynamic system and controller stability, code and standard application in design and specification, areas which he has some 17 years of experience of working on within National Grid since joining National Grid in 1996. Ben has extensive experience in the South East area of the network, in particular, Ben is currently leading the technical analysis and requirement specification of new compensation devices within the South East area to be delivered coincident with new Interconnector projects- for which SESG could provide key areas of information and understanding, and refinement.

Liena Vilde *(Power System Engineer)*

Liena is a Power System Engineer working in the area of future system operability, leading on the production of the System Operability Framework and the System Operation section of the Electricity Ten Year Statement. Her previous work has involved new technology implementation and balancing and ancillary services. Liena Joined National Grid in September 2011 as part of the Graduate Development Programme. Prior to that she received her MSc degree in Electrical Engineering and Renewable Energy Systems from University of Leeds in 2011 and BEng (Hons) degree in Electronics, Telecommunications and Internet Engineering from University of Bradford in 2010.

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 7: Organogram of the Project and Description of Partners Continued

Roberto Fernandez *(Power System Engineer)*

Roberto Fernandez is a Power System Engineer at National Grid. He works within Network Strategy, and focuses on the design and operation of the GB Electricity Transmission System, and applications of SMART solutions.

He joined the Graduate Development Programme in October 2013 and graduated with a first class degree in Electrical and Electronic Engineering from the University of Manchester in 2013.

Imperial College London

Below is a description of all the people from Imperial College that will be involved in the SESG project.

Goran Strbac *(Team Leader)*

Goran Strbac is a Professor of Electrical Energy Systems with extensive experience in modelling and analysis of operation, planning, investment and economics of all sectors of the electricity system including market and regulatory regime design. He led the development of novel methodologies for transmission network operation and design, including optimisation of preventive and corrective control strategies and evaluation of risk profile associated with smart grid paradigm. He led the development of the advanced whole-electricity systems framework for optimisation of the operation and investment of future electricity system, that has been extensively used to inform electricity industry, governments and regulatory bodies about the technical, economic and market challenges associated with transition to a lower carbon future including analysis of the role and value of emerging technologies. He co-authored 5 books and published over 160 technical papers.

Balarko Chaudhuri *(Deputy)*

Balarko Chaudhuri is a Senior Lecturer with research interest in electric power transmission systems, control theory, smart grids and renewable energy. Over the last 10 years he has managed and contributed to several research projects in the area of smart transmission grids which were sponsored by the research council in the UK and also major power sector manufacturers (ABB etc.) and utilities (National Grid, UK etc.), Electric Power Research Institute, USA. Recently, he developed novel control methodologies for HVDC and series compensation to improve transient stability of GB system and for provision of system services, particularly frequency support, through offshore DC grids. Dr Chaudhuri has published over 65 research papers in IEEE Transactions, IET Proceedings and leading international conferences. He has also published a monograph on 'Robust Control in Power Systems'.

Project Code/Version No: NGETEN02/V2

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 7: Organogram of the Project and Description of Partners Continued

Tim Green

Tim Green is a Professor of Power Engineering and Director of the Energy Futures Lab at Imperial College London. His research interests cover power electronics and control for future energy networks. This includes HVDC, control of FACTS (flexible AC transmission systems), integration and control of distributed and renewable generation, power quality improvement with distributed generation and micro-grids. He leads EPSRC's Energy Network's Hub, "HubNet" which is an 8 university consortium and is PI of the "Transformation of the Top and Tail" another 8 university consortium. He work with Alstom Grid on converter optimisation for HVDC and with National Grid and UK Power Networks of use of power electronics in energy networks. He has authored 160 conference papers and 65 journal papers with approximately 6,600 citations on Google scholar.

SIEMENS

Below is a description of all the people from Siemens that will be involved in the SESG project including the areas Siemens will support.

Colin Henry MEng, MBA, CEng, MIET (Project/Stakeholder Governance)

Colin is Head of Strategy and Innovation for the UK Energy Automation business, part of Siemens Infrastructure and Cities Sector; he leads Siemens innovation team within energy networks and integrated urban infrastructure. Colin has worked within the transmission and distribution field in the UK and overseas for almost 20 years. He has held a number of engineering, operational and strategic roles, including business transformation and change management. He has led Siemens smart grid positioning in the UK market, working with all the network operators as part of Ofgem's Low Carbon Networks Fund as well as wider engagement with industry, public and private sector.

Dr Vincent Thornley BSc EngD CEng MIET (Technical Governance)

Vincent is Portfolio and Technology Manager for the Energy Automation Business, part of Siemens Infrastructure and Cities Sector. Vincent has 20 years' experience of the energy industry, including manufacturing, academia, consultancy and technology provider. This experience crosses many technological boundaries: generation, power system protection and control, connection of renewable energy and smart grid technologies. In recent years, Vincent has led the team delivering business change and operational solutions for low carbon energy systems, flexible networks and integration with city infrastructure. Vincent is the recently appointed Chair for BEAMA's Smart Grid Task Force and will also have a seat on the DECC/Ofgem Smart Grid Task Force.

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 7: Organogram of the Project and Description of Partners Continued

Olamayowa Olabisi (Technical Design Authority)

Ola has considerable experience within the power industry at both transmission and distribution levels. Ola has previously worked for large power utilities in Nigeria and UK, including National Grid.

Ola is a senior applications engineer and has taken the Technical Design Authority role on previous LCNF projects, including the CLASS (Electricity North West, Tier 2) Project which included National Grid as a project partner. Ola has participated in learning dissemination events associated with the LCNF Programme, including speaking at the 2013 LCNF Event at Brighton.

Dale Geach (Expert Support)

Dale has considerable experience working with National Grid on Innovation Projects having successfully led the introduction of Operational Tripping Systems to the Transmission Network. Dale has significant knowledge of the transmission network in the South East having led the commissioning of the Sellindge Operational Tripping System and its interface transmission substations on the south coast. Dale will provide valuable experience during the delivery phase, including the installation of the monitoring system using Phasor Measurement Units.

Below is a description of all the people from UKPN that will be involved in the SESG project.

Alex Jakeman (Innovation Engineer)

Alex Jakeman is an Innovation Engineer at UK Power Networks with responsibility for delivery of innovative projects that ensure our distribution networks are able to meet the demands of a low carbon economy.

Alex joined the UK Power Networks Graduate Programme in 2013 and has previously worked for engineering consultancy AECOM, where he worked on the delivery of asset management strategies for water utilities. During his time with UK Power Networks, Alex has been involved in the Low Carbon Network Funded project "Low Carbon London" and has also worked on the design and delivery of several HV & LV reinforcement schemes. Alex received his MEng (Hons) in Civil Engineering from University of Exeter in 2011.

Project Code/Version No: NGETEN02/V2

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 7: Organogram of the Project and Description of Partners Continued

Sotiris Georgiopoulos (Low Carbon Senior Project Manager)

Sotiris Georgiopoulos is a Low Carbon Senior Project Manager within Future Networks at UK Power Networks with responsibility for developing and delivering smart grid projects. He is currently the Project Director of the flagship Low Carbon Network Funded project "Flexible Plug and Play Low Carbon Networks". Sotiris has previously worked in a number of engineering project management roles in the UK electricity generation and distribution industry.

Prior to joining the Future Networks team in June 2011, Sotiris was part of the UK Power Networks' 2012 Infrastructure Delivery team where he was responsible for project delivery of HV and HV/LV substations and the grid connections for the two CHP centres in the Olympic Park. Sotiris received his BEng (Hons) in Electrical & Electronic Engineering from University of Manchester's Institute of Science and Technology in 2003 and his MSc in Energy Systems and Management from the University of Dundee in 2004.

Chris Allen (Senior Manager Market Development)

Chris is responsible for ELEXON's engagement with smart grid stakeholders and represents ELEXON on the DECC/Ofgem Smart Grid Forum Workstream 3, 6 and 7 as well as the Smart Demand Forum and is an Executive Member of SmartGrid GB. Chris has supported a number of tier 2 LCNF projects with WPD, NPG, SSEPD and UKPN including Falcon (WPD), SAVE (SSE), GBFM (NPG) and Low Carbon London (UKPN). Chris oversees ELEXON's smart grid market development budget and has commissioned a series of major reports from top tier consultancies into community energy (Cornwall Energy), localised energy markets (DNV GL), energy storage (Poyry), demand side response (Frontier Economics) and active network management (Baringa and Smarter Grid Solutions).

Prior to ELEXON Chris worked for 12 years at British Telecom, latterly leading BT's smart metering programme, energy partnerships and leading on all energy efficiency investments across BT Group.

Chris reports into the ELEXON Senior Leadership team and is supported by a number of very experienced market design experts.

Appendix 8: Letters of Support

nationalgrid

National Grid House
Warwick Technology Park
Gallows Hill, Warwick
CV34 6DA

Ms Rhianne Ogilvie
Ofgem
Distribution Policy
5th Floor
9 Millbank
London
SW1P 3GE

Mike Calviou
Director, Transmission Network Service
UK Transmission

mike.calviou@nationalgrid.com

24 July 2014

www.nationalgrid.com

Dear Ms Ogilvie

Network Innovation Competition – South East Smart Grid (SESG)

National Grid Electricity Transmission (NGET) welcomes the opportunity for the 2nd year to engage in RIIO Network Innovation Competition.

The transmission and distribution networks in the south east are expected to accommodate significant volumes of non-synchronous generation in the form of wind and solar photovoltaic generation, as well as additional interconnectors to Europe. This combination will mean the current approach and tools used by the operators of the distribution and transmission networks will become increasing ineffective or inefficient and greater coordination will be required. The South East Smart Grid (SESG) project will allow new technical solutions to be trialled that address the interactions between networks and embedded generation, demand side services and interconnectors. This will establish those that are effective, provide system security and may subsequently be developed in to new products and services. Developing and trailing a coordinated control approach though this project will provide opportunities to reduce future services costs and potentially reduce or defer investment in infrastructure capacity to the benefit of consumers.

NGET has worked with a number of key partners in developing this project to ensure the range of activities and solutions are appropriately supported by those best placed to do so. Further partners may join the project as each stage is entered in to depending on the outcome of the previous stage assessment. NGET is committed to leading this project with the appropriate resource and expertise to assess the opportunities to provide secure, economic and efficient measures to manage whole system interactions.

Yours sincerely

Mike Calviou
Mike Calviou
Director, Transmission Network Service
UK Transmission

SIEMENS

Infrastructure and Cities

Dr. Vandad Hamidi,
SMARTer System Performance Manager
- Transmission Network Services

National Grid
National Grid House
C3
Warwick
CV34 6DA

Name	Paul Maher
Department	Managing Director Smart Grid Division
Telephone	+44 (0) 115 906 6702
Mobile	+44 (0) 7808 826385
E-mail	Paul.maher@siemens.com
Your letter of	
Our reference	
Date	15 July 2014

National Grid Electricity Transmission: Network Innovation Competition (NIC)

South East Smart Grid (SESG)

Dear Vandad,

Following your competitive evaluation process, Siemens is delighted to have been selected as a partner to National Grid for the South East Smart Grid (SESG) Proposal, to be submitted to Ofgem as part of the annual Network Innovation Competition (NIC).

The challenges faced today, of operating the south east electricity network are significant and these will be exacerbated by the future connection of low carbon generation, particularly solar and wind, along with the planned doubling of interconnectors to Europe. A lack of visibility of generation, storage and demand services connected at the distribution network, can distort power flows impacting the management of the transmission network.

Improved visibility and co-ordinated control of the whole electricity system in the south east through the SESG Project could provide significant benefit to UK plc in commercial terms, by reducing constraint payments to generators whilst allowing unrestricted flow of power through the interconnectors. The proposed SESG method is expected to develop a new suite of services and operational tools, in addition to those available to the System Operator today, to permit more effective management of the network

The SESG Project builds upon learning developed through previous IFI and LCNF projects, including a number in which Siemens have directly participated; the scope of SESG extends the control boundary to the whole electricity system, exploring the interaction between the transmission and distribution networks to reduce network congestion and the need to constrain low carbon generators, as well as improve network capability to permit unrestricted flow of power through the interconnectors to Europe. Research has shown that smart networks of the future will require a more 'whole system' approach to be adopted, involving dynamic, co-ordinated control between networks and markets for technical and commercial optimization respectively. The SESG Project will be a major step forward in helping the UK become a leader in coordinated control for the whole system and inform future investment planning.

Siemens is delighted to be part of a strong team of project partners with National Grid, including Imperial College London, Elexon and UK Power Networks; each partner has proven experience and delivery capability to make SESG a flagship project on a global stage.

Infrastructure and Cities Sector

Appendix 8: Letters of Support Continued

SIEMENS

Letter of 15 July 2014
to National Grid

Siemens has the local experience and capability to deploy solutions that fit the UK network and market needs using proven global technologies, we are committed to help National Grid and the other project partners with the learning and dissemination programme for the SESG project.

This is a truly exciting project with a strong business case that will deliver considerable value for network customers and UK plc as a whole. Siemens continually seek engagement in thought leading projects and is proud to be part of SESG with National Grid.

Yours sincerely

P. Maher

Paul Maher
Managing Director
Smart Grid Division - UK

SCF DL2008-09 Page 2 of 2

Imperial College London

Department of Electrical and Electronic Engineering
Imperial College London

Room 1103
South Kensington campus
London SW7 2AZ, UK
Tel: +44 (0)20 7594 6169 Fax: +44 (0)20 7594 6282

g.strbac@imperial.ac.uk
www.imperial.ac.uk/controlandpower

Prof Goran Strbac
Professor of Electrical Energy Systems

19 June 2014

Dr. Vandad Hamidi,
SMARTer System Performance Manager,
Network Strategy, Transmission Network Services
National Grid
Warwick Technology Park
Warwick CV34 6DA

Dear Vandad

South-East Smart Grid: Technology Options and Control Strategies

I confirm that Imperial College Imperial College London will be a partner of the SESG project.

We look forward to working with you in developing the final proposal.

Kind regards

Goran Strbac

Goran

Appendix 8: Letters of Support Continued

UK Power Networks
Delivering your electricity

Registered Office:
Newington House
237 Southwark Bridge Road
London SE1 6NP

Registered in England and Wales No: 3870728

Company:
UK Power Networks
(Operations) Limited

Vandad Hamidi
Smarter System Performance Manager
National Grid
National Grid House, C3, Warwick
CV34 6DA, UK

25th February 2014

Dear Vandad

National Grid's Call for Proposals for the South East Smart Grid project

In response to the above request, UK Power Networks would like to express its interest in engaging with National Grid to explore its participation in the project consortium for the South East Smart Grid project.

The main opportunity identified in the National Grid proposal is the development of a smart network that maximizes voltage, thermal and stability capability driven by the increased penetration of the distributed generation in conjuction with the existing generation already connected on the local distribution and transmission network and the operation of HVDC interconnectors. This opportunity is consistent with our experience of planning and operating the Southeastern network licence area of UK Power Networks and we welcome further discussions to explore the network opportunities and technical scope for the project. We believe that these are network challenges that can only be addressed through a joint distribution and transmission network approach.

The UK Power Networks contribution will be led by members of its 30+ strong Future Networks team with inputs from wider business experts as required. The Future Networks team comprises of a range of technical, commercial and project management experts in developing and delivering innovative solutions and projects. UK Power Networks through its IFI and Low Carbon Networks Fund (LCNF) portfolio demonstrates its commitment and track record on delivering benefits through innovation. The UK Power Networks team will also bring its invaluable experience in winning funding for five projects through the LCNF Second Tier, the only network operator that has been successful in each LNCF Second Tier competition in the four years the competition has ran.

I am looking forward to further discussing the proposals with you.

Yours sincerely

Martin Wilcox
Head of Future Networks
UK Power Networks

UTILITY INDUSTRY ACHIEVEMENT AWARDS 2012 UTILITY OF THE YEAR

Return Address:
UK Power Networks
237 Southwark Bridge Rd
Se 1 6NP
Martin.Wilcox@ukpowernetworks.co.uk

ELEXON

Dr Vandad Hamidi
SMARTer System Performance Manager
National Grid, National Grid House
C3 Warwick,
CV34 6DA
21 July 2014

National Grid Electricity Transmission: Network Innovation Competition (NIC)

South East Smart Grid (SESG)

Dear Vandad,

ELEXON is delighted to have been asked to support National Grid in the South East Smart Grid (SESG) Proposal, to be submitted to Ofgem as part of the annual Network Innovation Competition (NIC).

In our 2014/15 strategy we have committed to, "keep updated on changes in the smart grid field and assess potential impacts on the Balancing and Settlement Code arrangements" and this project is relevant to this strategic aim. The South East Smart Grid project will be testing a number of technical and commercial options that develop the potential for greater coordination of decentralised energy resources between transmission and distribution networks. In the future, system operation and balancing and settlement may not solely occur on a national basis and it is a great opportunity to review new commercial options to gain early visibility of potential future changes.

As the administrator of the Balancing and Settlement Code (BSC) ELEXON has responsibility to ensure the Code is given effect and we discharge our responsibilities in a way that better facilitates the BSC Objectives. Two BSC Objectives are particularly relevant in our involvement in this Proposal: *Objective B – the efficient, economic and co-ordinated operation of the national electricity transmission, Objective D – promoting efficiency in the implementation and administration of the balancing and settlement arrangements.*

ELEXON is delighted to support this project as we believe it has the potential to find ways to increase the efficiency of the electricity system and help evolve market arrangements.

Yours sincerely,

Mark Bygraves

Director Strategy and Development

Registered office 350 Euston Road, London NW1 3AW
Reg Co No: 3782949 REGISTERED IN ENGLAND AND WALES
ELEXON Limited 350 Euston Road, London NW1 3AW
T 020 7380 4100 **F** 020 7380 0407 **W** www.elexon.co.uk

Appendix 8: Letters of Support Continued

EDF ENERGY

Mike Calviou
Director, Transmission Network Service
UK Transmission
National Grid
Gallows Hill Rd
Warwick
CV34 8DA

11 July 2014

Statement of Support - South East Smart Grid, Network Innovation Competition Proposal

Dear Mike

I would like to confirm the support in principle of EDF Energy for the South East Smart Grid (SESG) proposal by National Grid (with partners UKPN, University Of Manchester, University Of Strathclyde, and Siemens) to the Network Innovation Competition.

EDF Energy is one of the UK's largest energy companies with activities throughout the energy chain. Our interests include nuclear, coal and gas-fired electricity generation, renewables, and energy supply to end users. We have over five million electricity and gas customer accounts in the UK, including residential and business users.

Our Dungeness B Nuclear Power Station is connected at 400kV within the focus area of the proposed project. This has been an area of significant system events over the past year. Additional system monitoring data, as per this proposal, would have augmented the analysis of network behaviour following these events, with subsequent improvements to system reliability.

We are aware, via our Nuclear Site Licence Provisions Agreement meetings with National Grid, of the future challenges in this area presented by new connections and interconnectors. The SESG project would help to improve the accuracy of power system modelling of these new developments.

In conclusion, we are supportive of the proposal and recognise the benefits that will come from enhanced system monitoring. We would be happy to see the data from the project as it progresses and to be presented with the project conclusions, as a final deliverable.

Yours sincerely,

Mark Cox
Head of Transmission & Trading Arrangements
Corporate Policy and Regulation

EDF Energy
40 Grosvenor Place, Victoria
London SW1X 7EN
Tel +44 (0) 20 7752 2200

edfenergy.com
EDF Energy plc.
Registered in England and Wales.
Registered No. 2366852.
Registered office: 40 Grosvenor Place, Victoria, London SW1X 7EN

This correspondence is a corporate communication issued by EDF Energy plc on behalf of EDF Energy Holdings Limited, (Reg. No. 06930266) and its subsidiaries

SP ENERGY NETWORKS

Vandad Hamidi
SMARTer System Performance Manager
Transmission Network Services
National Grid
Warwick, England

20th July 2014

Dear Vandad,

Re: National Grid Electricity Transmission plc:
South East Smart Grid (SESG)

ScottishPower Transmission are pleased to provide this letter of support for your South East Smart Grid (SESG) project.

ScottishPower recognise the value and the future of enhanced wide area monitoring technology; these are being studied and will be demonstrated at the transmission level as a part of VISOR. However, we do recognise that the significant challenge of an integrated monitoring system at transmission and distribution network.

The benefits of an enhanced monitoring system can only be fully realised if a coordinated control strategy is implemented. Such a control strategy will have appropriate access to new power electronic devices, energy storage, demand side management and distributed generation at both transmission and distribution level.

The ability to provide an effective control in a timely manner will reduce the existing network voltage and/or thermal constraints, improve the system dynamic responses and maximise the capacity of existing assets and hence achieve potential saving in network investment. The further released network capacity and the reduced need of new transmission lines will assist in the acceleration of new renewable connections, and in the case of South East Smart Grid, the new HVDC interconnection to Europe.

We look forward to discussing with NGET how the SESG project may become part of the business as usual arrangement where the project benefits may be shared among transmission licensees.

SPT look forward to the successful delivery of this project and the associated knowledge dissemination.

Yours sincerely

David Campbell

David Campbell,

Manager of Future Networks, SP Energy Networks

Ochil House, 10 Technology Avenue, Hamilton International Technology Park, Blantyre G72 0HT
Telephone 0141 614 0008
www.spenergynetworks.com

Scottish Power Energy Networks Holdings Limited
Registered Office: Ochil House, 10 Technology Avenue, Hamilton International Technology Park, Blantyre G72 0HT.
Registered in Scotland No. SC389555 VAT No. GB 659 3720 08

Printed on 100% recycled paper

SCP4494 Dec. 13

Appendix 8: Letters of Support Continued

WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales

Vandad Hamidi
SMARTer System Performance Manager
National Grid
National Grid House, C3,
Warwick,
CV34 6DA,
UK

Thursday, 17th July 2014

Dear Vandad

I appreciate the ongoing engagement with WPD through the development of your NIC projects, South East Smart Grid (SESG) and Enhanced Frequency Control Capability (EFCC). The areas both projects are investigating are forecast to become problematic in the future. Further they are likely to be difficult and costly to solve using conventional methods.

The solutions being investigated will have impacts on both the Distribution Network and Transmission Network and consequently warrant further investigation. Both solutions require careful design and operational coordination between the DNO and TSO to ensure that both networks operate safely and effectively at all times.

If successful in the NIC competition, both Project Solutions could deliver benefits to all GB consumers. I am therefore happy to provide this letter of support and look forward to hearing the outcome in the Autumn.

Yours faithfully

Philip Bale
Innovation and Low Carbon Networks Engineer

Western Power Distribution (East Midlands) plc.
Registered in England and Wales No. 2366923
Registered Office:
Avonbank, Feeder Road, Bristol BS2 0TB

Western Power Distribution (West Midlands) plc.
Registered in England and Wales No. 3600574
Registered Office:
Avonbank, Feeder Road, Bristol BS2 0TB

Project Code/Version No: NGETEN02/V2

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 9: List of Previous Projects

We have identified a number of previous projects related to the SESG project with valuable knowledge that will support the successful delivery of the project. A summary of these related projects in addition to the key learning points that they bring to the SESG project are outlined below.

A9.1 National Grid Humber SmartZone

The Humber SmartZone pilot project has been developed as a "non-built" solution against reinforcement option in the East Coast where a number large offshore windfarms are expected to connect. National Grid will investigate the effective utilisation of transmission assets when offshore windfarms are at their maximum output. Initial analysis has already been carried out as part of "phase 1" to demonstrate the feasibility of the concept. This concept will now be proven on the transmission system during the "phase 2" which will be carried out between 2014 and 2017.

The Humber SmartZone learning suitable for SESG:

- ✓ Installing Phasor Measurement Units
- ✓ Installing Random Access Memory Units
- ✓ Upgrading Communication System
- ✓ Intelligent operational inter-trip scheme
- ✓ Overhead lines dynamic thermal rating
- ✓ Congestion Management
- ✓ Alarm and protection setting optimisation

For more information on the Humber SmartZone project, please refer to the project submission here: http://www.smarternetworks.org/Project.aspx?ProjectID=1455

A9.2 ENW Customer Led Ancillary Services Support (CLASS)

This ENW's tier 2 LCNF project partnered with Siemens demonstrated a low risk transferable solution which automatically or on request delivers ancillary services. The Method delivered a zero carbon and non-intrusive provision technique for ancillary services required by National Grid and future DSOs.

With this project, ENW is able to explore the ability of its distribution networks to deliver each of the following responses, in support of the responsibilities of NG for system balancing as the Transmission System Operator (and potentially in the future Distribution System Operators) using Siemens innovative solutions.

- Frequency Management – fast reaction to system frequency to maintain network stability by adjusting generation-load balance
- Reactive Power Management – absorbing reactive power from higher voltage network by staggering transformer tap positions apart
- Load Management (Demand boost/reduction) – temporarily increasing load to prevent constraint boundary problems. This response is more usefully generalised into a 'balancing and system security' provision which could be called upon to support system constraints and (technical) balancing actions.

Appendix 9: List of Previous Projects Continued

The CLASS project learning suitable for SESG:

- ✓ Local distribution control scheme
- ✓ Frequency Management
- ✓ Load Management
- ✓ Voltage Optimization
- ✓ Pre-funded
- ✓ Distribution automation

For more information on the CLASS project, please refer to the project submission here: https://www.ofgem.gov.uk/ofgem-publications/46074/class-isp.pdf

A9.3 Northern PowerGrid Grand Unified Scheme (GUS)

The project was developed and deployed as part of Northern Powergrid (a UK distribution network operator)'s Customer Led Network Revolution (CLNR) project. A major component of the CLNR project is the implementation of a Grand Unified Scheme made up with a combination of existing novel network devices. The aim of the GUS was to demonstrate increased network flexibility and capability by coordinated action (control and monitoring) of enhanced network devices. The core of this project was in co-ordinating those devices so as to solve problems like thermal and voltage constraints on the network.

The project has been deployed using a combination of local and central intelligence to deliver flexible, scalable and expandable intelligence. It placed decision-making in the appropriate location, using appropriate methods to maintain models with minimum effort, while localizing decisions wherever possible to obtain maximum distributed benefit.

The GUS project learning suitable for SESG:

- ✓ Central and Local distribution control scheme
- ✓ Constraint Management
- ✓ Voltage Optimization
- ✓ Pre-funded
- ✓ Distribution automation

For more information on the Customer Led Network Revolution project, please refer to the project submission here:
https://www.ofgem.gov.uk/ofgem-publications/45882/cet2001-addendum-and-pro-forma.pdf

A5.4 Low Carbon London

The aim of this project is to investigate how 'smart grid' technologies can be used to help meet the increased demand for electricity. Field trials are conducted to mimic future scenarios where electric vehicles, smart meters and local generation are common place and where businesses and individuals can play an increasing role in reducing carbon emissions.

Appendix 9: List of Previous Projects Continued

The Low Carbon London learning suitable for SESG:

- ✓ Smart meter trials involving over 5,800 customers in the London area
- ✓ Smart control of electric vehicle (EV) charging points - currently monitoring 77 residential, 66 commercial and more than 1,250 public charging points.
- ✓ Decentralised energy trial which is investigating new Active Network Management (ANM) automation and control techniques.
- ✓ Demand response from industrial and commercial customers

For more information on the Low Carbon London project, please refer to the project submission here: https://www.ofgem.gov.uk/publications-and-updates/low-carbon-networks-fund-low-carbon-london-full-submission-proforma-submitted-edf-energy-networks

A9.5 Flexible Plug and Play

Distribution Network Operators face the challenge of accommodating high concentrations of distributed generation connections on the electricity network. In this context, the aim of the Flexible Plug and Play project is to enable cost effective and timely integration of distributed generation electricity connections, such as wind and solar farms. The trail is conducted on a part of the network in Cambridgeshire where 144MW generation is currently connected to the grid and an additional 200 MW is at the planning stage.

The Flexible Plug and Play learning suitable for SESG:

- ✓ New commercial arrangement allowing the DNO to manage the output of the distributed generator to ensure the network constraints.
- ✓ High-speed telecommunications platform for advanced control and monitoring.
- ✓ Trial smart technologies including active network management (ANM), automatic voltage control, dynamic line rating, novel protection scheme for reverse flows and RTUs interfaced with ANM

A9.6 Project VISOR

Visualisation of Real Time System Dynamics using Enhanced Monitoring (VISOR) was the 2013 NIC submission from Scottish Power Transmission (SPT). National Grid was selected as a partner for the project and a lot of the learning from this project will be suitable for SESG.

VISOR learning suitable for SESG:

- ✓ Wide Area Monitoring
- ✓ Detection of Sub-Synchronous Oscillation
- ✓ Detection of Inter-Area Oscillations

A9.7 America OG&E's Smart Grid

The project has been tried in Oklahoma with a regulated utility company that serves over 750,000 customers in Oklahoma and western Arkansas. The five year project will be completed in three years due to running different aspects of project in parallel.

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 9: List of Previous Projects Continued

The OG&E's Smart Grid learning suitable for SESG:

- ✓ Advanced metering infrastructure
- ✓ Distribution automation
- ✓ A range of in-home technologies
- ✓ Dynamic pricing programs

A9.8 America Ruston Smart Grid

The project was funded as part of "U.S Smart Grid Investment Grant Program". The initial funding was around £2.5m in October 2009 to its delivery of £5m. The main objective of the project was to provide 21000 residential properties with 10596 electric meters.

The Ruston Smart Grid learning suitable for SESG:

- ✓ Advanced metering infrastructure (AMI)
- ✓ Meter data management system (MDMS)
- ✓ Pre-funded
- ✓ Distribution automation

UK Power Networks

South Eastern Power Networks Plc
Main Transmission Network

Note: Not all distributed generation is shown on this plan.

ISSUE 23	SCALE	DRAWN	CHECKED	APPROVED	DRAWING NUMBER	ISSUE
Distributed generation details added	1:200,000 @ A1	Russell Hawkes (P.J.Kerr 08-01-91)			132_33NET.DGN	23

16-05-14