RIIO NIC NETWORK INNOVATION COMPETITION

Project Code/Version No:
SSEN02/2.0

Electricity Network Innovation Competition Full Submission Proforma

Section 1: Project Summary

1.1 Project Title:

Modular Approach to Substation Construction (MASC)

1.2 Funding Licensee:

Scottish Hydro Electric Transmission plc (SHE Transmission)

1.3 Project Summary:

SHE Transmission proposes to demonstrate and deploy a permanent substation designed using a Modular Approach to Substation Construction (MASC). The current approach to substation construction differs little from that of 60 years ago; meanwhile many innovations in design and civil engineering could create a substation which is cheaper, faster to deploy and more suited to GB's low carbon energy future. MASC seeks to prove the following benefits:

- **Faster deployment:** MASC maximises off-site construction so that timescales associated with extensive, on-site civil engineering works are shorter.
- **Improved whole life asset value:** MASC substations could offer up to 20% savings over an asset's whole life, compared to conventional builds. This equates to £151m to £655m savings across the GB transmission network.
- **Increased flexibility for network configuration:** MASC capacity can be easily modified to suit changes in generation plant capacity.
- **Improved environmental impact:** MASC's smaller geographical footprint and off-site construction ensure improvements in visual amenity and less disruption to local communities, wildlife and land.

The project is expected to last for approximately five years, providing incremental learning and new standards in substation design and operation. Two innovative learning tools will be introduced through the project; a MASC 3-D Virtual Simulation Tool and a MASC Decision Tool. NIC funding is sought to cover only the additional costs of demonstrating MASC for the first time.

1.4 Funding

NIC Funding Request (£k): £2,835

Network Licensee Compulsory Contribution (£k): £326

1.4.3 Network Licensee Extra Contribution (£k): n/a

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

1.4.5 Total Project cost (£k): £3,263

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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):

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:

The MASC project does not require the recruitment of official project partners to meet its objectives.

Nevertheless there are a number of project supporters from within the supply chain; these are [redacted]. Support is required from the supply chain so that essential technical solutions required for MASC are made available to transmission operators. Letters of support for the project can be viewed in Appendix 2.

There are no external funders for this project; the only funding sought from NIC is the additional cost of deploying MASC for the first time, including funds required for knowledge dissemination to interested parties, and adaption of industry standards to allow industry-wide application of MASC.

1.7 Timescale

1.7.1 Project Start Date:	**1.7.2 Project End Date:**
01 January 2015	28 June 2019

1.8 Project Manager Contact Details

1.8.1 Contact Name & Job Title: Frank Clifton Project Development Manager	**1.8.3 Contact Address:** Future Networks and Innovation, Inveralmond House, Scottish and Southern Energy Power Distribution, 200 Dunkeld Road, Perth PH1 3AQ
1.8.2 Email & Telephone Number: frank.clifton@sse.com 01738 456237	

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Section 2: Project Description

This section should be between 8 and 10 pages.

Appendix 12 may be used to offer the reader additional support; this appendix contains details of all external links and sources referenced throughout the main submission documents.

2.1.a Aims and Objectives

SHE Transmission are planning to build a significant number of new substations between now and 2026, which are necessary to (i) facilitate the connection of renewable energy generation, and (ii) expand and reinforce the network to create infrastructure which accommodates necessary extra capacity. **The objective of this NIC project is to build, deploy and demonstrate a new, permanent substation using a Modular Approach to Substation Construction (MASC)**. The NIC funding request covers the **additional costs** of deploying a MASC substation for the first time; the actual substation project cost will be covered using the industry's established commercial mechanisms for connections.

The Modular Approach to Substation Construction (MASC) project will incorporate a range of new innovations which have not been tested together at scale in Great Britain, to create a functional specification that will be demonstrated in a new substation construction project. These innovations include new approaches to substation component installation but also incorporate novel approaches to civil works associated with substation construction, such as trenching, foundations and improved visual impact design. Stakeholders' input will be incorporated into the visual design elements. The key output will be a new, standardised configuration for substations.

There are financial benefits associated with this approach; economies of scale and flexible components create reductions in costs which can be passed to transmission customers. Modular substations facilitate extra capacity easily, creating extra options and flexibility to incorporate network changes. The type of modular substation proposed is permanent in nature and overall, the proposed solution aims to give better whole life value than traditionally built substation assets.

The MASC methodology has strong potential for application across SHE Transmission and other transmission operators' substation portfolios. This includes substation projects for new connections, refurbishment and reinforcement and distribution-led connections across all voltages.

The key benefits from MASC arise primarily from the optimisation of off-site construction to reduce the time and duration of on-site activities, with associated reductions in building and civil costs. This move to a modularised solution must be balanced within the practical limitations on transportation and lifting. Therefore, the MASC methodology can be most readily applied to substations which operate at the lower voltages and have relatively straightforward connection requirements.

SHE Transmission recognises that deploying this solution at higher voltages will create additional challenges due to the increased scale of the plant involved. However, international experience has shown that higher voltage modular solutions can be successfully deployed. SHE Transmission has selected to trial the first MASC solution on a single, 132kV connection bay substation supporting a single transformer for a new, renewable connection. There are several reasons for this: there are significantly more 132kV than 275kV or 400kV projects planned throughout RIIO:T1; many of these are likely to be situated in remote locations. Learning from this first deployment will provide a firm foundation for applying the solution at higher voltages and in more complex network configurations. Many of the elements will be directly applicable at higher voltages, especially changes in design requirements, construction, commissioning and operational techniques. MASC will provide a range of benefits including:

Increased value for money: Early calculations demonstrate that using MASC could create cost savings of up to 20% in comparison to a conventional build. If it is assumed that the MASC methodology could be deployed in between 30% to 50% of substations in the GB transmission network from now until 2050, MASC potentially creates financial benefits of between £151m and £655m (using calculations based on National Grid's Electricity Ten Year Statement's Slow Progression and Gone Green scenarios).[1] A full description of the methodology used to calculate value for money is contained in Appendix 7a, and Sections 3 and 4 of the main submission document.

Benefits come from several elements of MASC;

- Standardised components offer serial production opportunities and thus, economies of scale;
- Off-site manufacture and commissioning will reduce costly on-site construction and commissioning timescales;
- A smaller footprint signifies a reduced need for foundations and civil works;
- Increased flexibility to meet capacity reduces the risk of stranded assets;
- Maintenance and fault repair is more economical because individual modules can be interchanged, so that maintenance is completed off-site, minimising circuit down time.

Information on benefits is provided in more detail in Sections 3 and 4.

Potential for reduction in timescales for planning and consent processes: A smaller geographical footprint and improvements in visual and environmental impact may help to establish planning consents in a timely way.

Quicker deployment lead times due to off-site manufacture: Modularised substations use rapid-build components which can be transported on trailers or within containers to the nominated site, appreciably reducing the time it takes to construct and commission a new substation. Once on site, the substation is simply put into place with reduced foundations; this is a faster process than that of a conventional substation build, where components are transported separately and the substation is assembled and commissioned on-site.

Improved flexibility in response to network changes: A modular substation may also better suit the changing requirements of the transmission network in the future. One of the key benefits of using a modular substation is the added flexibility and optionality it offers in adapting to network changes. The establishment of new generation plant, repowering of existing generation and decommissioning of assets will be more easily accommodated by adding or decreasing new modules as necessary.

Improved quality of build: Modular substations are assembled in a clean and controlled factory environment, with many elements of testing and commissioning done in situ, before the equipment is despatched to site. This reduces the time required on site for these activities. This approach may also lead to a corresponding increase in quality, because unlike on-site builds, the construction takes place in a clean environment.

Reduced environmental impact: Advanced design means that modular substation components are more compact than traditional models. This type of approach may cause less disruption and noise during the on-site installation phase. The smaller footprint requires less concrete and thus, a reduction in the volume of stone delivered to the site. This in turn requires fewer vehicle movements, and causes less damage to roads. As much of the work is done off-site, there is also a reduction in temporary works associated with on-site construction, such as temporary generators, lighting, security, and car parking. These types of improvements may help reduce timescales in the planning and consent stages of a substation construction project.

The difference between a conventional and a MASC substation construction can be described using the analogy of a traditional, bespoke house build project compared to a pre-cut or "Hufhaus" home. A traditional, bespoke house build project is unique, with its own design specifications. Raw materials are brought to the site and the materials are then worked on to create the final design. Meanwhile, a pre-cut home is mostly built off-site using quality, prefabricated components with high calibre design options. An example of this can be shown in Figure 2.a below:

Figure 2.a – Example of pre-cut home which uses a modular approach

At the moment, substations are bespoke in design and build – using a MASC or "pre-cut" approach may offer transmission operators improved costs and flexibility, and quicker deployment speed.

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Project Description continued

2.1.b Electricity Transmission in the UK

Great Britain's electricity transmission grid consists of a high voltage network of power lines and substations owned by SHE Transmission Ltd, Scottish Power Transmission Ltd (SPT) and National Grid Electricity Transmission Ltd (NGET), referred to in this document as transmission operators or TOs. The GB transmission network was created in the 1930s and is one of the most complex and interconnected grids worldwide, designed to have high levels of resilience and reliability. The transmission network is designed for the bulk transport of energy over longer distances and its lines and cables are often thought of as the "motorways" of the electricity network, with the lower voltage, distribution network classed as the "A" and "B" roads. A technical description of a substation can be viewed in Appendix 3, and SHE Transmission's network diagrams and maps can be viewed on Appendix 11.

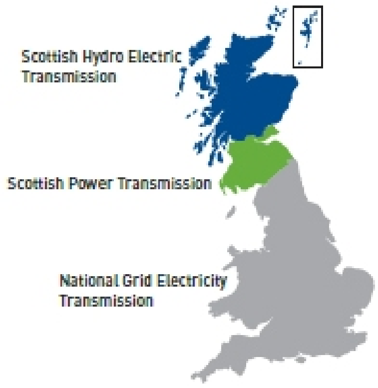

Figure 2.b Map of UK networks by operator

The design of the transmission network has not changed a great deal since the 1960s; plant equipment, including substations, is built to have an asset life of over 40 years. This suits the connection of predictable and controllable generation sources like coal or gas fired power stations, and accommodates well understood and largely static demand profiles. The existing national infrastructure has served GB customers very effectively, providing a secure energy supply and a safe, efficient network for many years.

However, transmission operators are currently facing the simultaneous challenges of (i) GB decarbonisation (ii) an increasing dependence on intermittent energy generation sources (iii) a growing reliance on electricity and (iv) a need to minimise costs to customers. Future demand patterns on the distribution network will become increasingly unpredictable as a result of customer-led changes (such as participation in community energy schemes, the use of low carbon vehicles and the rise of microgeneration). This will have a follow on impact on the transmission network, leading to an unprecedented need for new and upgraded transmission infrastructure. The Institute of Engineering and Technology's "Handling a Shock to the System"[2] advises that:

"These changes are potentially disruptive to electricity supply security and the cost effective operation of the grid, and this will become progressively more severe."

2.1.c A need for new infrastructure – the future transmission network

The UK Government has set an ambitious target for the deployment of renewable energy generation over the next decade, as described in the Carbon Plan[3] (p16):

"Around 30% of our electricity is likely to need to come from renewables alone by 2020 in order to meet our legally binding EU target to source 15% of the UK's energy from renewable sources by that date."

As a result, all GB transmission operators have a steady number of renewable energy developers looking for connection to the grid. For example, an extract from National Grid's Transmission Entry Capacity register[4] (at 20th May 2014) showed that SHE Transmission has 8.5GW of new, renewable generation planned between 2014 and 2026, while National Grid Electricity Transmission has 70GW and Scottish Power Transmission has 6.7GW. To meet these demands significant investment in new transmission infrastructure is required.

Traditionally, the country has relied on a relatively small number of large fossil-fired power stations. According to National Grid's "Electricity Ten Year Statement"[1], a key change to the network will involve the transition from these centralised, stable and predictable generation plants to intermittent, variable sources such as wind solar, tidal and wave. These types of renewable energy sources are much more geographically diverse and likely to be in remote locations, and power will need to be exported over longer distances to reach demand points.

In addition to the connection and management of new, intermittent energy generation, transmission operators have extensive work plans to replace ageing assets, refurbish and reinforce existing assets and increase voltage on lines to create a safe, reliable and efficient network that meets the needs of a low carbon economy.

A number of transmission projects are in development to deliver a modern network infrastructure which can accommodate these new challenges. SHE Transmission estimates that up to 3.9GW of new substation capacity is required within its network area between 2014 and 2023. This substation capacity needs to serve variable and intermittent generation, possibly from remote locations, and increasingly dynamic and flexible demand from consumers, while maintaining network resilience. This offers an unprecedented opportunity to demonstrate the benefits of innovative substation technology which has been proven as having distinct benefits in other parts of the world but has not yet been established in GB.

2.1.d The Problem

Currently, substations are designed and built based on the methodology developed in the 1960s. The design, construction and deployment elements of a substation in GB are done on a near "bespoke" basis. Each substation is designed with its own set of distinctive criteria based on technical requirements, local geography and environment, visual amenity, and the connections the substation needs to facilitate. Specialised transport and access arrangements are often required due to the size and weight of components. Low risk asset management and replacement strategies means that improvements in substation design have been limited to small, incremental changes on an individual basis. Images and descriptions of substations and their components are described in Appendix 3.

An exceptional but necessary level of investment is planned for the GB electricity network; The SHE Transmission Business Plan (2011)[5] indicates that an expected investment of between £3bn and £5bn in its network will be required, depending upon the timing and scale of renewable generation deployment (NGET and SPT also have significant infrastructure investment plans). Much of the cost of the investment will be borne directly by customers. All of the network operators have similar investment programmes, which include substation investment, giving rise to a number of specific challenges including:

- **Whole Life Value**: Transmission operators need to continue to strive to seek best value for money from their asset portfolios.
- **Costs and supply chain**: Substations are traditionally designed on a near bespoke basis. This does not offer opportunities for economies of scale in terms of equipment and supplier costs.
- **Substation consents**: Substations are known as being visually detractive to the local landscape and can be inefficient in terms of land use. This results in negative visual amenity impacts, onerous consent processes and high land costs.
- **Design Standards**: Traditional design criteria tend to the peak demand requirements of the connections. Conventionally built substations work very well with fossil fuel fired generation plant but future generation will be much more diverse and requires extra flexibility including substation capacity.
- **Flexibility**: Traditional substations are very 'permanent' in nature; there is little scope for easy and low-cost options for expanding or redeploy capacity according to new or decommissioned generation points around them.
- **Asset Life**: Existing standards and designs are based on a long asset life (typically more than 40 years). While this has suited the network for the last 60 years, it is likely that substation requirements will need to change to accommodate new generation plant, and the repowering and decommissioning of existing assets.

The conventional approach to substation construction creates reliable, robust and efficient equipment which has performed well against the demands of the network for the last 50 years. However, many new innovations in substation technology have emerged across the world which have not yet been tested in the GB utility environment. A deployment and demonstration of some of these new technologies could potentially create a substation solution which has reduced construction timescales, offers better value and is more flexible than the traditional model.

2.1.f The Method

SHE Transmission proposes to deploy and demonstrate a Modular Substation on the live transmission network. While the actual cost of the substation will be borne using the established industry practises, NIC funding is essential to fund the additional costs of implementing MASC for the first time. This funding will be used to allow SHE Transmission to show the required leadership for the industry and develop the tools and techniques to facilitate the widespread adoption of the MASC approach. The funding will also provide learning capture and knowledge dissemination, data gathering, reporting, engagement with other network licensees, the supply chain, and environmental, planning and consent stakeholders.

Using NIC to fund the extra components of the MASC project will enable the benefits to be shared throughout the industry, creating savings for GB transmission customers. SHE Transmission would not at this time consider MASC deployment without NIC support because in doing so, the result is another 'bespoke' or 'niche' substation developed in isolation specifically for SHE Transmission. To exploit the full range of benefits from the MASC solution requires its adoption across the industry to encourage competition amongst potential vendors and achieve economies of scale. Substations have been largely bespoke until now and this has served the GB network well, but as described in Section 2.1.d, a step change is required to ensure best value and flexibility for GB transmission customers in future years. SHE Transmission believes that MASC can be a key contributor to this.

A range of substation-related innovations have been proven and incorporated into the global marketplace, but have not been tested together at scale in GB. This includes the modularisation of substation components but also other innovations associated with civil work, construction methodology and environmental impact. These innovations are currently being evaluated through SHE Transmission's NIA-SHET-0013 project (see Appendix 13).

As described in Sections 3 and 4, all of the benefits which arise from cost reductions in infrastructure projects will flow directly to transmission customers. The benefits which will arise from reduction in the cost of connection projects will be shared between transmission customers and connection customers (primarily renewable developers).

The actual cost split is governed by the requirements of National Grid's Connection and Use of System Code (CUSC), but typically the infrastructure element of the connection project, which is recovered from transmission customers, comprises up to 25% of the project total. The remaining sole user costs are borne by the connection applicant. The move to a modular solution will be applicable to both the sole use and infrastructure elements of the project, therefore, both should benefit from reductions of up to 20%.

The use of a modularised approach will require new strategies in terms of operational practises and procedures in order to realise all of the potential benefits. Without proof of concept, transmission operators in the highly regulated GB environment are unlikely to implement a modular approach within their business as usual practice in the short term. Trial and demonstration is therefore required, supported by innovation funding, to fully explore and validate the potential benefits of a modular approach to substation construction.

Overall, the modular approach will reduce the time it takes to deliver and commission a new substation, and will have a reduced environmental impact compared to conventional models. The use of this approach will also allow a progressive, flexible approach to operation and maintenance whilst maintaining safety and reliability standards. MASC also introduces a "next generation" approach to substation design which can be used to enable serial, rather than bespoke, production of substations, providing economy of scale. The testing, demonstration and learning from this NIC project will give GB transmission operators confidence to apply the MASC solution on a wider basis and develop standards that are conclusive to this approach.

2.2. Technical description of project – the trials

The project will include the design, deployment and demonstration of a MASC substation. Note that NIC funding is required only for the incremental costs of deploying this approach for the first time. MASC methodology is applicable to SHE Transmission and other transmission operators' substation portfolio across the grid, but for the purposes of the project, will be used to connect a new renewable generation development to the transmission network at 132kV. The NIC MASC project will follow on from the ongoing NIA-SHET-0013 project (see Appendix 13). The **NIC** project will then commence with the following dates, phases and deliverables, implementing the learning from the ongoing NIA project:

MASC Phase One – Planning (January 2015 – February 2016)

Phase One comprises of the selection and refinement of the standardised technical specification as delivered by SHE Transmission's NIA project, and stakeholder engagement to align requirements with the generation source to be connected, as follows:

Stakeholder engagement. This includes work with internal stakeholders to ascertain an appropriate site for substation deployment. SHE Transmission will identify a developer through the established industry procedures in conjunction with National Grid. Mutually agreed commercial arrangements will be established with developers and with substation suppliers if appropriate. Consultations with planning authorities and other statutory bodies will be sought and their input incorporated into the functional specification where possible.

Identification of the final specification. The final technical specification will be identified and will factor in the following elements:

- Options for off-site construction and preparation;.
- Advancements in civil engineering which improve access and transport constraints for new substation build projects;
- New containerised substation components such as switchgear and transformers.
- Safety and optimal operational standards;
- Improved visual amenity;
- Ground conditions; and
- Flexibility in increasing or decreasing capacity to match local generation units and their anticipated asset life.

Deliverables at this phase will be concerned with technical and commercial documentation:

i. Confirmation of a site for the first MASC deployment.
ii. Recommendation papers following input key stakeholders on planning consents and visual amenity.
iii. Commercial agreement with a prospective renewables developer, if appropriate.
iv. Technical documents of the final functional specification.
v. Protection system requirements and specification.
vi. Overall footprint requirements, including civil and access requirements.
vii. Options for potential expansion, contraction and redeployment of equipment.
viii. Bilateral agreement with a substation manufacturer.

MASC Phase Two – Construction (March 2016 – September 2018)

Phase Two involves planning consent and construction of the new substation. In addition, this phase will incorporate evaluation of the civil works and transport/access:

Planning consent: SHE Transmission will seek approval from the appropriate planning and consent authority depending on the proposed location the substation will occupy, and its size. Early learning will be captured which evaluates the impact of MASC against a conventionally built substation in terms of costs and timescales through the planning and consent process.

Construction of the MASC build: All construction which can take place off-site will be completed and be tested and commissioned, after which the equipment will be transported to site so that construction can be completed. This will also include a move where appropriate to off site commissioning.

Development of operational processes and tools: New industry operational and safety practices and processes will be developed for familiarisation, training and for the preparation of knowledge dissemination.

Development of MASC tools: If required a suite of method-specific tools and equipment will also be developed for operations, maintenance and repair.

Deliverables at Phase Two include:

i. Evaluation of improvement in planning process in conjunction with a MASC build.
ii. Completed construction, commissioning, initial testing and connection of the MASC substation to the grid.
iii. Energisation of the substation and generation plant.
iv. A manual of operational, safety and maintenance procedures.
v. A series of MASC tools and equipment.

MASC Phase Three – Operation (April 2017 – March 2019)

Phase Three will see the MASC substation through approximately two years of operation:

Initial deployment: The substation will be commissioned. Early testing will take place to ensure that the substation is performing as it should.
Operation: The substation will be fully placed into operation and monitored against a range of scenarios, managing exports from the generation plant onto the grid.
Deliverables at Phase Three include full commissioning of the substation and approximately two years of operation.

MASC Phase Four – Monitoring and evaluation (April 2016 – March 2019)

Monitoring and evaluation: In addition to the standard protection and control equipment used to monitor substation performance, a series of extra monitoring controls will be put in place to evaluate the substation's performance compared to a similar build using conventional design methodology. This will monitor the substation's operation within a range of scenarios. The deliverables include functional specifications to allow further applications in the GB market.
The project will be structured in such a way that it shares learning from the early stages i.e.

during the detailed design phases. In addition, the overall project duration allows for an extended period of monitoring and evaluation once the equipment is in service to ensure that it is performing as expected. Deliverables for knowledge and dissemination include the standard progress and closedown reports as well as a programme of knowledge dissemination, described in Section 5. However, the principal deliverables will include:

- A MASC Decision Tool which allows other transmission operators to compare the cost benefits analysis of commissioning MASC substations compared to conventional builds;
- A MASC Three-Dimensional Virtual Simulation Tool for operational training, and for planning. This will also assist stakeholder to understand the benefits of a MASC approach; and
- Evaluation of this approach on the environment i.e. the number of vehicle movements, and the impact on geology, hydrology and local wildlife.

The substation build will be funded via established industry mechanisms for private connections. The NIC funds will be used only to cover the additional costs of implementing, evaluating and monitoring the MASC build for the first time.

2.3. Description of design of trials

The project is divided into six distinct work packages with knowledge captured and disseminated incrementally. There are several ways in which the project has been designed with robust working practice and knowledge dissemination as key priorities:

a) Evaluation at each stage will include benchmarking against a traditional substation construction project so as to clearly define learning outcomes. This will include analysis on value for money so that customer benefits can be clearly shown.
b) Extra monitoring which may include a range of measures will be installed in order to consolidate learning. This will be determined following the selection of the equipment provider.
c) The project will follow SHE Transmission's regular governance and project process work to ensure good oversight.

The six work packages are; Project management; Scoping requirements; Construction; Operation; Monitoring and evaluation; and Knowledge dissemination

Please see Appendix 5 for details of the work programme.

2.4. Changes since ISP

SHE Transmission has continued to develop the MASC concept since the ISP. This has allowed us to begin to more clearly identify the issues and problems which MASC will help to address. This has resulted in a more comprehensive set of requirements which has allowed us to better define the costs and programme for the project.

Section 3: Project Business Case

This section should be between 3 and 6 pages.

3.1 Business Case Context

Please note that supplementary information for this section can be found in Appendix 7.

SHE Transmission's core purpose is to provide the energy people need in a reliable and sustainable way. More specifically, SHE Transmission's statutory duties as a transmission licensee are: to ensure the development and maintenance of an efficient, coordinated and economical system of electricity transmission; to facilitate competition in the supply and generation of electricity; and to have due regard for preservation of amenity.

The drive toward a low carbon electricity sector and in particular, the growth in renewable generation, has created a wide range of challenges for the transmission network and the wider electricity sector. These challenges are placing an increasing demand on Transmission Owners (TOs) to provide the new capacity required to connect this renewable energy generation. New infrastructure is therefore required, which demands considerable investment. The construction of new substation infrastructure is an essential part of this new challenge, not only to provide the necessary capacity to accommodate new renewable developments but also to provide the interconnectivity required to maintain system security and integrity. SHE Transmission has an established asset management policy which seeks to balance three main factors: cost, risk and performance. The company's aim is to achieve satisfactory network performance at an acceptable risk and within the constraints of efficient cost. Across all of SHE Transmission's activities, safety is given first priority.

The company's ultimate stakeholder is the GB electricity consumer; people who pay electricity bills have a legitimate interest in how costs are derived.

3.2 Integration with SHE Transmission's Business Plan

"Innovation with a purpose" is central to the company's strategy of providing the energy people need in a reliable and sustainable way. The Innovation Strategy, described in SHE Transmission's business plan[5] (2011) commits the company to seven high-level innovation objectives. The MASC project will deliver learning which will contribute directly to the delivery of the majority of these objectives:

- Accelerating network development and connections including the integration of increasing amounts of renewable generation - by providing faster connections.
- Minimising the cost of providing network capacity – by securing economies of scale from serial production and optimising off site construction.
- Maximising the use of existing assets to deliver capacity and speed connection – reduced deployment times for modular substations will allow new infrastructure to more closely match the capacity of the generation assets which are being connected.
- Maintaining and improving network performance – the use of a modular substation approach will provide a more flexible asset which can be more easily redeployed in order to meet changing network demands.
- Remaining at the forefront of innovation to maintain the company's record of providing the highest standards of service at the lowest possible cost – the MASC project will allow

GB TOs to take advantage of advances in technology which have been successfully implemented in other parts of the world.

SHE Transmission is confident that the MASC project will complement and support the company's Innovation Strategy[5] and will help to meet the company's core objective of providing the energy people need in a reliable and sustainable way**.**

3.3 Motivation for the Development of MASC

Traditionally, transmission substations have been developed on a near bespoke basis and once operational, are relatively "fixed" with limited flexibility to either increase or decrease capacity. Improvements in substation construction methodology have been delivered in small and conservative increments.

Analysis carried out by TNEI on behalf of SHE Transmission shows that up to 1,337 new substation projects may be required on the transmission network alone between now and 2050 (see Section 3.8 for details). DNOs in England and Wales are likely to have similar requirements. This will incorporate demand for new connections, but also refurbishment and infrastructure projects and work to create capacity increases at grid supply points. SHE Transmission is investing heavily to upgrade and reinforce the network, with a £3bn - £5bn investment programme in progress.

As identified in National Grid's Future Energy Scenarios (2012)[1], there is a wide range of potential scenarios for the development of the GB transmission system, all of which will require a significant investment. Even the least optimistic projections still envisage significant numbers of renewables being connected to the network, all of which will require additional substation infrastructure.

3.4 Benefits for Customers

The MASC methodology has strong potential for application across SHE Transmission's and other transmission operators' substation portfolios. This includes the full range of voltages, and project type, whether this be reinforcement and refurbishment, DNO connection at a grid supply point, or a new, renewable connection.

The solution that MASC will enable however, will deliver particularly strong benefits for customers; all of the benefits for TO reinforcement, refurbishment projects and their equivalent DNO projects in England and Wales will flow directly to transmission customers. Meanwhile, the benefits for connections are likely to deliver benefits to both renewable developers and transmission customers, depending on the particular circumstances in relation to the established CUSC protocols (see Appendix 7 and Section 4.b). For this project, it is likely that MASC will be used to deploy and demonstrate a 33kV-132kV substation which connects a new, renewable generation development to the transmission network. This provides an opportunity to demonstrate the benefits of the MASC solution and will give confidence to expand the solution to other network scenarios.

3.5 Benefits for Transmission Operators

The MASC project will deliver a number of benefits for TOs; many of these benefits will flow directly to customers:

Reduced costs: Equipment suppliers are increasingly offering innovative modular substation components which have been proven in other sectors. This will offer further opportunity to further rationalise the range of components and potentially achieve economies of scale from a more serial approach to production.

Increased flexibility: The use of a more modular solution where “modules” can be added or removed relatively easily will allow the altering of capacity in response to changing network demands in a timely way.

Transport and access costs: Much of the new substation infrastructure being developed is required in order to connect new renewable generation. By its very nature this is likely to be in some of the most remote and inaccessible areas of the country such as the Scottish Highlands, rural parts of Wales and the West Country. Traditional substation designs require significant civil works and transport arrangements. The modular equipment being proposed is designed to be transported and installed easily on site, reducing the requirement for civil works. This should reduce the overall cost of construction.

Footprint and civil works: traditional substation components require significant space and separation in order to maintain the appropriate safety clearances and separation distances. The use of a more modular design will facilitate a reduced overall footprint and less complex civil requirements.

Off-site manufacture: The use of a modular approach will maximise the use of off-site manufacture and commissioning. This should significantly reduce the time required to install and commission the equipment on site, which is particularly beneficial for projects located in remote areas. This should serve to reduce cost and improve flexibility. The move to a more controlled factory based commissioning regime should also produce corresponding improvements in quality. It may allow for a greater range of more specialised commissioning test to be undertaken which will result in improvements in reliability.

Reduced construction duration: As identified above, a modular approach will look to optimise the use of off site manufacture and commissioning, which combined with the reduced civil works requirement, will result in shorter time being required on site. This reduction in site time will result in reduced establishment and management costs. The use of an off-site manufacture and commissioning should also see a reduced number of vehicle movements to deliver equipment to site.

Asset life: Existing standards and designs are based on a long asset life (of over 40 years) which is likely to be significantly longer than the anticipated life of many of the renewable developments seeking connection. In many cases wind farm developments have planning consent for around twenty five years of operation. At the end of this period there is the potential that the wind farm may seek consent to continue generating or it may be “repowered”, potentially with larger machines. This combined with potential changes in demand profiles in the future will present an increasing requirement for a flexible network which can respond to these potential future changes. In the event that the generation development reaches the end of its asset life and is decommissioned, a modular substation can be more readily relocated to another site.

Reduced operating costs: Where there is a sufficient population of modular equipment connected to the system there is the potential to have "spare" modules which can be easily "swapped" with modules already connected to the system. These modules could then be either maintained on-site or returned to the manufacturer. This has the potential to reduce costs and outage times.

3.6 Benefits for Other Network Licensees

The learning from the MASC approach has potential to deliver benefits for the other TOs and other network licensees, including Distribution Network Operators (DNOs) many of whom have 132kV equipment connected to their networks. The learning from the MASC project will be directly relevant to DNOs, which are facing similar issues to the TOs.

3.7 Benefits for Renewable Developers

Renewable developers are key customers and stakeholders for all TOs. The benefits from the MASC project discussed throughout this document will be of advantage to renewable developers. The potential reduction in the cost of substation infrastructure will improve the financial viability of some marginal projects which as the additional benefit of helping GB to achieve its renewable obligations. Financial benefits relating to renewable connections are governed by National Grid's CUSC rules, which are described in greater detail in Appendix 7.

3.8 Financial Benefits from MASC

3.8.1 Future Infrastructure - Number of Substations Required

In order to understand the potential number of projects which could benefit from the MASC approach, an assessment of the current identified projects in GB was undertaken. Broadly, these can be split into two areas, load driven and non-load driven. SHE Transmission has also used the current projects identified in National Grid's Transmission Entry Capacity Register[4] to assess the scale and size of the developments currently planned for connection to the transmission system. This covers the next seven years of development and identifies the projects' current status.

In order to fully understand the benefits of MASC in the long term, National Grid's Electricity Ten Year Statement[1] analysis was used to estimate the total number of potential projects that may be connected by 2050 based on the current data. SHE Transmission has also considered projects identified in the various DNOs' Long Term Development Statements. In the Ten Year Statement, three scenarios are considered; Slow Progression; Gone Green and; Accelerated Growth. For the purposes of this submission SHE Transmission will consider the 'Slow Progression' and 'Gone Green' to assess the potential financial benefits.

For the purposes of this analysis, SHE Transmission has assumed that developments under 30MW are likely to be connected directly to the distribution system at 33kV or below.

A similar analysis of the various TOs' and DNOs' business plans was undertaken by TNEI to identify the number of non-load related projects; this analysis provides numbers of potential projects, which can be seen in Figure 3.a. Further details on this analysis are described in Appendix 8.

No of projects by 2050	Slow Progression Scenario	Gone Green Scenario
NGET/NG(DNO)	319.8	692.9
SHE Transmission	173.7	376.5
SPT	123.3	267.4
Total	**616.8**	**1336.8**

Figure 3.a Table of total number of potential substation projects in UK between 2014-2050

Given that the MASC approach is particularly suitable for new substation sites, SHE Transmission believes that it will be appropriate for a significant proportion of the projects identified above. For the purposes of calculating the benefits SHE Transmission has assumed that MASC will be appropriate for between a third and half of the above projects.

3.8.2 Typical Substation Costs

Using a combination of historic costs and project design information SHE Transmission has identified that the total cost of a substation can be broken down into several elements, as described in Appendix 7.

In order to quantify the benefits SHE Transmission has looked at the typical cost of a substation. This has been based on the information contained in TOs' Charging Statements[6] and compared with typical cost data. From this analysis SHE Transmission has identified that typically the total cost of a 60-90 MVA substation is between £3.5m and £6.5m. For the purposes of this analysis SHE Transmission has assumed an average cost of £4.9m per substation. The actual cost will depend upon the specific rating, location, and other aspects of planning and deployment.

MASC has the ability to reduce costs in a number of areas, in particular, reduced on-site infrastructure, site establishment, project management, buildings, etc, as shown in Figure 3.b. Based on the company's early engagement with the supply chain and an initial assessment of potential cost reductions, SHE Transmission believes that the overall cost of a substation could be reduced by up to 20% over a whole asset life basis. There are risks associated with the transition, which are detailed in Section 4; for this reason, and to ensure all TOs may learn from this project, NIC funding is sought.

Based these initial assumptions the potential benefits from MASC are outlined in Figure 3.b.

No of projects by 2050	Slow Progression	Gone Green
Total number of potential substations	617	1337
[redacted]	[redacted]	[redacted]

[redacted]	[redacted]	[redacted]

Figure 3.b – Table describing the potential for financial benefits from MASC application

Therefore, SHE Transmission believes that the MASC project will deliver benefits up to £655m, the majority of which will be passed directly to transmission customers. Further details of cost benefits analysis are included in Appendix 9.

The key benefits of MASC focus on providing **value for money, delivering wider environmental benefits to customers**; **and disseminating knowledge**.

4.a. Accelerating the development of a low carbon economy/delivering environmental benefits while delivering net financial benefits to customers

(i) The reduction of carbon emissions, while not directly influenced by MASC, will be facilitated by the project. Benefits provided by MASC, such as shorter timescales between construction and deployment, a focus on off-site construction, and cost savings will help ensure that TOs are able to continue providing cost efficient connections for new renewable developments. This will help to reduce the overall cost of new generation projects which will play a part in maintaining the overall financial viability of these projects and deliver the objectives of the Carbon Plan.

(ii) MASC will provide additional options and flexibility which will help ensure that the Transmission network can deal with changing demands in the future. This is particularly relevant for future scenarios where repowering of existing renewable developments will provide new challenges for network owners.

(iii) MASC will deliver environmental benefits by helping ensure the continued connection of new renewable developments. In addition to this, widespread application of MASC will deliver other environmental benefits, as defined in Figure 4.a.

MASC methodology	Expected wider environmental benefits to customers
Increase in off-site construction/reduction in on-site construction	• Reduction in noise levels, vibration and air pollution caused by construction work and site traffic, both at the site and in the vicinity; • Reduced physical impact on land and road surfaces caused by heavy goods vehicles carrying wide and heavy loads to site, also reduced number of vehicle movements to site with materials, workers, and plant equipment; • Reduced cost associated with reinforcement work to bridges, culverts and roads; also reduced cost associated with worker welfare including the provision of welfare buildings, portacabins and parking; • Reduced need for sterilisation of land after decommission of assets; and • Reduced need for waste material disposal caused by components arriving for on-site construction.

Reduction in footprint and associated civil works	• Reduced foundation requirements and associated carbon emission equivalents of concrete use; • Reduced earthworks and less impact on soil, land and local geology, including effects on peat etc; • Reduced impact on soil and land also lessens effect on wildlife; • Reduced need for tree felling and clearance of surrounding flora and fauna; and • Reduced impact on local hydrology and need for drainage and; • Reduced overall carbon emissions.

Table 4.a Expected wider environmental benefits to customers provided by MASC

(iv) The base case cost for a substation project is estimated to be £4.9m. MASC can save up to 20% of this cost over the whole asset life of the substation, which equates to a saving of up to £980k. Extrapolated to 669 substation projects across GB between 2014 and 2050, net benefits of up to £655m could be achieved by MASC deployment. This can then be passed to customers. This is fully explored in Section 3 of this document and in Appendices 6 and 7.

4.b. Provides value for money to electricity transmission customers

(i) The Direct Impact of the MASC method will mark a step change away from historical, bespoke substation technical designs to a standardised, "pre-cut" approach; this is measurable in terms of cost savings, and reduced construction timescales for substations. Benefits will come from the reduced capital and operational costs of MASC. Deployment of MASC on a wider scale, and the consequential benefits of this, will enable network licensees to implement measurable cost savings for end consumers and developers, as detailed in Sections 3 and 4. The method also has wider environmental benefits as discussed earlier in this section of the document. The MASC approach can be applied to the full range of substation projects. This includes:

- Wider infrastructure projects as well as projects for the refurbishment and reinforcement of the transmission systems operated by the three TOs, and also equivalent projects carried out by DNOs on the 132kV system in England and Wales; and
- New connection projects on the transmission system – these are generally to facilitate the connection of new renewable generation developments.

Benefits from Infrastructure, Refurbishment and Reinforcement projects: When the substation assets are being installed for reinforcement or refurbishment, the assets are classed as infrastructure, and therefore **all** of the benefits from the MASC will flow directly to back to transmission customers. Similarly, benefits will flow to distribution customers if the MASC solution is applied by a DNO. From the analysis included in Appendix 6a , these account for approximately half of the overall number of anticipated projects.

Benefits from New Connection projects: For new connection projects the total cost of the projects are split between two categories, namely connection charges and infrastructure charges. Connection charges relate to the costs of assets installed which are require solely as a result of the new development – these costs are borne solely by the connectee. Infrastructure charges relate to the recovery of costs related to the wider transmission network (where assets may be used by a number of different users) and are socialised amongst all users of the transmission network. The cost split between sole user charges and infrastructure charges are determined in accordance with the CUSC (Connection and Use of System Code). There are a wide range of factors which will influence this cost split including, network configuration, rating, voltage, location etc. For a typical new connection project the Infrastructure element will consist of the overhead line connection (if it exceeds 2km), and the incoming HV switchgear and ancillaries at the new substation. The cost of the associated transformers, LV switchgear etc, are all included in the Sole User costs. The incoming HV circuit breaker will form part of the modular substation and will be largely constructed and commissioned off-site. As identified in the table below a conventional AIS type substation, this incoming circuit breaker and its associated protection and control equipment and other ancillaries can form up to 25% of the total cost of the substation.

Infrastructure	Cost (£k)	Quantity	Total (£k)
132kV Busbar Bay	£ [redacted]	[redacted]	£ [redacted]
132/33kV (90MVA) Transformer	£ [redacted]	[redacted]	£ [redacted]
33k Busbar Bay	£ [redacted]	[redacted]	£ [redacted]
		Total	[redacted]

Table 4.b Costs based on SHE Transmission's 'Transmission Owner Charges April 2014'

The initial assessment of the benefits identified during the development of the full submission suggest that the overall cost of the substation will be reduced by up to 20%. Therefore it is anticipated that the cost of the 132kV busbar bay identified above will be reduced by up to 20% - these benefits will flow directly to Transmission Customers. The remaining elements of the Infrastructure Charges (overhead line, etc will not be impacted by the use of a modular substation). The benefits of the reduction in the cost of the transformer bay and 33kV equipment will see a reduction in the sole user charges which will benefit the generation developer.

(ii) The scale and cost of the project compare favourably with the value of the knowledge and learning that the project will provide. Section 2 describes current plans among network operators to expand and reinforce their networks, and MASC will provide key learning which enables all operators to achieve best whole life value for money from new substation investment. Outputs from the MASC project will benefit all GB electricity TOs.

(iii) The project will be delivered at a competitive cost; NIC funding is only requested for the additional costs of delivering a MASC substation for the first time. Expenditure will be carried out within SHE Transmission's strict governance processes and an appropriate competitive procurement procedure used to secure the equipment.

(iv) The use of modular substations will provide benefits to all transmission network customers. The way the benefits are shared amongst the various stakeholders will be dependent upon the project where the MASC technology is being applied i.e. whether this is to accommodate a connection from a new generation source or is being deployed as a part of the TO's planned works on the network. The extent and share of the benefits will also be influenced by the specific site details i.e. the location, rating and network details for the site.

(v) The MASC project will involve extensive stakeholder engagement to ensure that solution meets as many of their requirements as possible. However, key to the successful implementation of the project is to have a robust understanding of the products are available in the market place and how these could be employed in a GB context. To this end , SHE Transmission has worked closely with its established supply chain partners to gain a deeper understanding of the equipment and the benefits it may bring, This facilitates understanding of the challenges and issues which SHE Transmission may face in applying this approach in a GB context. Letters from [redacted] have been received in support of the project (see Appendix 2).

(vi) There are no costs associated with protection from reliability or availability incentives.

(vii) SHE Transmission is engaged with the supply chain to ensure that there will be appropriate participation from potential manufacturers and fulfilment of products and services if MASC is successful. SHE Transmission uses competitive procurement processes for all purchases of goods and services and all procurement activity is transparent and responsible.

(vii) The MASC project will fall under SHE Transmission's established governance processes to ensure value for money. The functional specification for MASC, and learning capture will be available to all relevant electricity network licensees and the supply chain; extensive knowledge sharing will consolidate best value for money.

(viii) While most of the funding for this project will be met by a developer, SHE Transmission seeks £2.835m from NIC and will also make a contribution of £326k. This funding covers only the additional costs of using MASC for the first time; this will include knowledge capture and dissemination, and extra monitoring and evaluation. The benefits from the MASC project are described in detail in Section 3.

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

The development of a modular approach to substation construction will enable the generation of new knowledge from the projects and studies undertaken within it. A full description of the plan to capture learning is included in Section 5.

(i) The project has been designed to optimise learning and knowledge within every phase of the project; planned outputs are described in Sections 2 and 5. Key learning outputs which will be made available throughout the MASC project include:

- Detailed substation functional requirements and specification;
- Protection system requirements and specification;
- Overall footprint requirements, including civil and access requirements;
- Impact on environmental concerns associated with the site, such as hydrology, drainage, and geology;
- Options for potential expansion, contraction and redeployment of equipment;
- Visual impact of new functional specifications;
- Utilisation / load profiling especially when looking at renewable connections;
- Validation of costs; and
- Stakeholder considerations – planners, environmental regulators and supply chain.

(ii) Knowledge from the project will form the basis for investment level confidence amongst GB network licensees, planning authorities and the supply chain. The methodology of MASC can be applied across all of the network licensees' substation portfolios, although this particular project will focus on a 33kV-132kV renewable connection.

(iii) A clearly defined knowledge dissemination programme is described in Section 5. In addition to a programme which includes reports, workshops and seminars, SHE Transmission proposes to introduce two innovative tools for knowledge dissemination. The first of these is a decision tool which will be made available to network licensees to provide quick and easy cost-benefit analysis for substation planning. The second is a three-dimensional virtual simulation tool which allows users to "tour" the substation and view operational and maintenance procedures. This approach will help provide the operational training required in order to implement this new solution. More details of these innovations are described in Section 5.

(iv) SHE Transmission will use a standard framework to capture results from the project. Knowledge will be disseminated through various methods which are further detailed in Section 5. The project plan has included appropriate financial and manpower resources for knowledge dissemination activities. Learning capture is defined throughout the project's SDRCs. Knowledge and learning content is peer reviewed and follow governance processes to ensure robustness before publication or presentation, as appropriate.

(v) It is our intention that the work undertaken using NIC funding will adhere to the NIC default IPR arrangements. However, this will be subject to confirmation depending upon the final outcome of the commercial negotiations with equipment suppliers, project partners and other stakeholders. In all negotiations SHE Transmission will strive for maximum availability of the Project work for dissemination and sharing purposes.

4.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

(i) MASC is innovative in several ways. The project demonstrates an electrically innovative way of constructing and deploying substation components, many novel in themselves, in a modular way. The project also combines a range of civil innovations to complete the substation deployment. Demonstration of a modular substation at this scale has not been implemented before; while there are clear benefits associated with the MASC project, there is a need for one transmission network operator to show initiative and take the lead in the delivery of a modular substation on the live network for the first time. This deployment and the associated learning will bring confidence to the industry to adopt this new approach. This will give the opportunity to achieve economies of scale and also will give the momentum to encourage both TOs and the supply chain to develop solutions for higher voltage and more technically complex scenarios.

There has been limited use of some containerised components or temporary substations in GB and in other countries; however, several permanent, wholly modular substations have been successfully integrated into networks outside of GB; see Appendix 4 for examples of this. The success in other countries and engagement with the supply chain give SHE Transmission enough confidence to believe that this approach could be modified for application in the GB environment. Substation design, construction and operational techniques have changed very little over the last sixty years. This project represents a "step change" in substation design and practise, which inherently includes additional cost and risk to implement for the first time. Without the support from NIC it would not be possible for an individual TO to progress this approach. Similarly, this use of NIC funding allows the knowledge to be shared amongst all network licensees, this gives the potential for further economies of scale and will encourage greater supply chain involvement.

(ii) MASC is a project that SHE Transmission could not undertake as part of its normal course of business, because proof of concept concerning the deployment of a fully modular approach for a permanent substation has never been established in GB. The only NIC funding sought is that which is required for the additional costs of implementing MASC for the first time. NIC funding and SHE Transmission's compulsory contribution will cover the costs of the following aspects of the project:

- Refining the final functional specification;
- MASC specific operational, maintenance and deployment processes;
- Knowledge dissemination;
- Stakeholder engagement and evaluation and monitoring;
- Engagement with the supply chain to gauge product availability and potential for application of a wholly modular approach in GB; and
- Engagement with SHE Transmission environmental specialists to understand issues and challenges related to current and historic substation build projects.

These elements will look beyond the site specific details of the first application to allow for a more widespread application of the MASC approach.

(iii) The MASC project poses several risks. These include challenges to existing safety, operational and technical standards and practises. The off-site fabrication and commissioning is novel to GB and at the moment there is no consolidated place in the GB market for MASC. A fully modular solution with associated innovations in civil works has not been tested at scale in GB. A range of assumptions need to be validated and the entire project will require careful monitoring and evaluation to ensure that MASC can be successfully rolled out in GB. These risks mean that SHE Transmission cannot bear the cost burden of the additional costs of deploying MASC for the first time using BaU funding. The aim of the MASC solution, if proved during the trial and adopted by other network licensees, is to lead to widespread benefits to customers and the environment. However, if the project were to be carried out using BaU funding, SHE Transmission could not cover the extra overheads of knowledge capture and dissemination, monitoring and evaluation etc. This then precludes other licensees from understanding the benefits the solution could offer. Were SHE Transmission the only network licensee to adopt the solution, there is no need for a strong supply chain in terms of equipment and the end result is yet another 'bespoke' substation arrangement. Learning and knowledge dissemination are discussed in details in Section 5 of this document.

4.e Involvement of other Project Partners and External Funding

(i) SHE Transmission has made a deliberate decision not to recruit project partners but instead to incorporate in-depth stakeholder engagement within Phase 1 of the project. There are advantages to this approach; the functional specification will be openly offered to the supply chain, generating a robust and competitive marketplace for future procurement. This also ensures the functional specification can have input from all GB-wide distribution and transmission network licensees rather than just one or two licensees. Inviting a wide range of environmental, planning and consent stakeholders to participate in Phase 1 facilitates understanding of this type of substation well ahead of wide-spread GB roll-out, and assists licensees in understanding a range of issues related to substation construction projects.

Supply chain: SHE Transmission has sought to ensure that collaboration with the supply chain is robust. Meetings between various manufacturing suppliers and SHE Transmission, facilitated by SHE Transmission's procurement specialists, have been encouraging, with letters of support of the project received from [redacted].

Network licensees: SHE Transmission have had high level discussion on the MASC project with Scottish Power Transmission and National Grid, and also Southern Electric Power Distribution. All have agreed that MASC offers significant potential for future benefits in terms of environmental impact as well as cost savings for customers. An open invitation will be extended to all electricity network licensees to participate throughout Phase 1 of the project. In addition, a comprehensive programme of knowledge capture and dissemination will be carried out to ensure best value from the NIC funding. In developing the MASC bid, feedback and comments on previous substation-related bids were considered.

The MASC project focuses on the deployment and demonstration of a modular substation. This will be connected to the live network, either as a reinforcement or new renewable generation connection. SHE Transmission will therefore have a contractual obligation to make the connection within agreed timescales. This is a key driver in the decision not to recruit formal project partners – in order to ensure contractual agreements are met, it was felt that formal project partners could pose a risk, and therefore it is considered essential that SHE Transmission are the sole controllers of this project.

(ii) SHE Transmission conducts a programme of stakeholder engagement which includes ongoing communication with the supply chain, and attendance at industry events. Ongoing engagement is undertaken through surveys, workshops and events, as well as one-to-one meetings. This includes frequent meetings with the supply chain for initial appraisal of new technologies which have been developed in other areas of the global marketplace to gauge their value and potential adaptation for the British transmission industry. Throughout the year, a series of SHE Transmission internal workshops are held to identify, score and prioritise potential projects and check for best match against business as usual, Technology Steering Board, Network Innovation Allowance and Network Innovation Competition funding streams.

The concept for the MASC project arose as a result of internal stakeholder engagement aimed at seeking solutions to existing problem statements and discussions with trusted, established manufacturers. In the case of MASC, there appeared to be scope for solving existing issues around substation construction by adopting new innovations which had been proven in other regions of the world. MASC and all other potential project ideas are scored against (a) alignment with the SHE Transmission Business Plan[5] and Innovation Strategy; (b) their potential for helping SHE Transmission contribute to the Carbon Plan and the European Commission's 2020 targets for the connection of renewables[7]; and (c) suitability for help through potential funding streams or business as usual funding, as appropriate.

The ideas' level of project readiness and scope for integration into business as usual processes is also taken into account. Research is undertaken to ensure there is no replication across the industry and to understand current learning on the key objectives the project looks to achieve. Initial approval to proceed with the project may then be sought by SHE Transmission's senior management team.

The NIC governance document references the ENA collaboration portal; this was checked with no potential project partners listed.

(iii) The MASC project does not require a formal partner arrangement although the project team will work with various organisations; these organisations are not required to seek other collaborators.

(iv) SHE Transmission has engaged with internal stakeholders and with the transmission supply chain to ensure in-house and procurement collaboration.

(v) NIC and SHE Transmission funding is only to cover the additional costs of delivering a MASC build for the first time; these costs include procuring the equipment for the first time, additional monitoring and evaluation, and knowledge dissemination. The majority of the cost of the project will be met by SHE Transmission's established business practices.

4.3.f Relevance and timing

(i) The primary area of business planning which would benefit from the MASC project is the increasing requirement for TOs to provide network capacity for new renewable energy generation, which is being driven by the move to a low carbon electricity sector in GB. MASC is relevant to all electricity network licensees for several reasons;

- Knowledge from the MASC project will inform all GB TOs. The connection selected for the demonstration is a 33kV-132kV substation; however, the MASC solution could be applied at any voltage from 132kV to 400KV.
- Knowledge will be delivered incrementally over the project lifecycle. MASC will be connected by 2017; two years of operation will then be evaluated to give network licensees the knowledge and tools required to factor MASC into their substation development plans from 2018 and throughout the 2020s.
- All TOs have a responsibility to reduce carbon emissions and accommodate renewable energy connections to the grid to meet the Carbon Plan budgets; application of the MASC method across GB can make a contribution in the third and fourth Carbon Budgets (2022 and 2027 respectively).

(ii) Over the coming decade SHE Transmission expect to expand its transmission network significantly to facilitate the growth of renewable generation in the north of Scotland. If the method proves successful, SHE Transmission and other GB TOs can use the decision tool described in Section 5 to compare cost benefits between conventional builds and MASC builds for future substation projects. TNEI has estimated that SHE Transmission will require between 173 and 377 substations in its territory between now and 2050, using National Grid's Electricity Ten Year Statement's Slow Progression and Gone Green scenarios, with other GB TOs having similar new infrastructure needs. A description on this analysis can be viewed in Appendix 6.

4.3.g Demonstration (i) of a robust methodology and (ii) that the project is ready to implement

(Please note that this section is described in the Ofgem NIC Governance publication, but not in the Notes on Completion of the Full Submission documents; to ensure Ofgem receives all of the information it requires, this section has been added to this submission.)

(i) SHE Transmission has created a robust plan for the project's delivery, with all responsibilities clearly detailed and interdependencies identified. The work programme can be viewed on Appendix 5.

(ii) The MASC project is supported at all levels within SHE Transmission, via the established Innovation Steering Board, senior management will be involved in the development and operation of the project. A dedicated project manager will be appointed to deliver the MASC project; a budget has been created and checked to ensure that sufficient resource is allocated to the project's delivery.

(iii) The project will begin on 01 January 2015; the project plan evidences timescales and key delivery deadlines.

(iv) MASC does not involve any interaction with, or possibility of supply interruptions to, end consumers and therefore there is no customer impact associated with the project

(v) The costs estimated are based on a combination of historic experience of implementing and delivering innovation projects combined with information gathered during our engagement with the supply chain. This has been used to create consistent and accountable budgets for all projects. These are peer reviewed before being passed to senior management for approval. All of SHE Transmission activities are subject to review and internal audits and are maintained in a state of readiness for such activities.

(vi) There are no plans to request contingency funding, other than that indicated in Section 6.

(vii) If MASC is proven through the project, it can be deployed on an individual basis using the decision tool which will be created as part of the project's knowledge dissemination programme. The methodology MASC applies is based on conservative estimates of savings i.e. in a range between 10% and 20%, and evidence based on application studies where a modular approach has been deployed in other countries.

(viii) The Successful Delivery Reward Criteria are detailed in Section 9. These have been reviewed by SHE Transmission's Future Networks Management Team to ensure that they are of sufficient substance and quality.

(ix) The submission has been reviewed by SHE Transmission's Regulation and Legal teams. Key data has been checked by TNEI, the consultancy organisation appointed to support SHE Transmission. The submission has been through several peer reviews and has been approved by SHE Transmission's Innovation Steering Board and Directors.

(x) All SHE Transmission projects are subject to the company's governance and oversight processes. These include passing a series of "gates" with specific, measurable targets for each gate. In addition, the project manager will have a project oversight manager to ensure compliance and as a point of escalation in the event of issues. Risk registers and mitigation measures are set in place to pro-actively manage the project and identify areas of concern. A copy of the MASC project's risk register and contingency plan can be viewed in Appendix 8.

(xi) SHE Transmission projects are executed in such a way as to ensure careful management and expenditure. Issues are flagged at and in-between project review "gates" and a clearly defined escalation procedure is followed so that, in the event of concern e.g. it is considered to be uneconomical or ineffective in terms of outcomes, including benefits to customers, the project may be halted. In the event of a halted project, a process is in place so that no further withdrawals can be made from the project's bank account. In this instance a closedown report and all other governance concerning the project would still be required.

Electricity Network Innovation Competition Full Submission Proforma

Section 5: Knowledge dissemination

This section should be between 3 and 5 pages.

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

5.1 Introduction

SHE Transmission adopts clear learning objectives, defined as a discreet work package and supported by established knowledge management procedures. This approach ensures that the capture and dissemination of learning is measurable, appropriately monitored and resources, and becomes an integrated part of every stage in the project. The high-level learning objectives identified for this project are outlined below; these will be supported by detailed work plans with clear deliverables and milestones during the project.

5.1.1 Learning Objectives

- **New Substation Requirement:** Detailed design requirements and functional specification produced in this project will be directly applicable to the roll-out of further modular substations. While 132kV is the selected voltage for this initial trial, the functional specification used for the build will be applicable for substation connections between 132kV to 400kV. Specifications developed will include protection system requirements, footprint, civil and access requirements.
- **Performance, Operability and Maintenance Requirements:** Additional monitoring and measurement of the new equipment during the operational phase will provide confidence that the substation is performing as anticipated.
- **Future Usage Options:** A suite of potential sites for future deployment of the MASC will be developed during the project, highlighting the geographic and business scenarios which are most appropriate for use of the technology.
- **Supply Chain Capability:** The project will engage with suppliers to identify a range of solutions and innovative technologies applicable to modular substation design, deployment, operation, and maintenance. While not all solutions will be applicable to this trial, a database of suppliers, innovations, and capabilities will be of significant value to future projects.

5.1.2 Dissemination Tools

SHE Transmission is continually adapting the tools used to effectively disseminate knowledge to internal and external audiences. The plan outlined below is based on our experience and feedback from previous dissemination activities and is intended to facilitate and accelerate the adoption of this learning into business as usual for all network licensees. Varying levels of technical detail will be employed to engage a wide stakeholder base; this is detailed in the 'Targeted Communication' section below.

Progress and Completion Reports: Progress reports will be completed at every stage of the project, and the final outcomes and learning of the project will be compiled in a closedown report; these will contain sufficient detailed, technical information to enable transmission licensees to use MASC as a design option.

Knowledge dissemination continued

Hosted Dissemination Events or Webinars: At significant milestones SHE Transmission will host events for other TOs and interested parties to present learning to date and encourage questions and feedback on the content.

Conferences: The project aims, development and results will be displayed and presented at a variety of relevant conferences including LCNI and All Energy, with handouts being used where appropriate; this is an efficient way of raising the profile of the research and increasing traffic to the webpage and attendance at dissemination events.

ENA Learning Portal.

SSEPD Website and Press Releases: A dedicated project page on the SSEPD Website will provide updates on the current stage of the project as well as links to download reports and links to other relevant projects. Press releases will also be used to raise awareness of the project at key milestones.

MASC Decision Tool: A decision tool will be developed as part of this project which provides a cost-benefit analysis of a modular substation compared to a conventional build for a given set of parameters. While this will be a relatively high-level comparison tool, providing a 'quick-and-easy' method for initial cost-benefit analysis will improve awareness of MASC as an option and pave the way for adoption to business as usual.

MASC 3-D Virtual Simulation Tool: An accessible virtual simulation of the MASC will be developed for this project. The tool allows the user to 'walk' around the plant and provides information about each item of plant, as well as the function of each control. In this way users can simulate operation and maintenance procedures on the plant, significantly reducing the training time required for new operators on site, and allowing stakeholders and students to explore the substation without the need for costly travel or the risks of being on-site.

SHE Transmission's knowledge management procedures

Reapplication of experience

SHE Transmission staff are aware of the need to learn from previous research; literature reviews plus stakeholder consultation will be part of the development of detailed studies to achieve the learning objectives above. This will help ensure that the MASC outputs generate new learning. Where necessary, studies and learning objectives may be refined to ensure the project builds on current knowledge rather than reproducing it.

Continual learning capture

The capture of formal technical learning relating to the objectives above will be supplemented by reflection on the process of project delivery to identify lessons learned. The project team has built a schedule of lessons learned reviews into the outline project plan, and will refine this schedule during the course of the project. Findings from lessons learned reviews will be validated by SHE Transmission's internal Project Review Board and disseminated to relevant groups.

Knowledge dissemination continued

Targeted communication

We recognise that different groups will have different interests in the learning generated by the MASC project and that dissemination is most effective when the messages and methods are tailored to the audiences' needs. Our dissemination will focus on the following groups, using the methods outlined below:

Transmission owners/Other network licensees

GB TOs are the primary audience for learning from the MASC project because they are largely responsible for the development of new substations. Learning outcomes will improve confidence to select a modular substation where the cost-benefit analysis is favourable. Results from extended monitoring will enable informed procurement and operational decisions, and a 3-D simulation will improve operational training. The project will enable TOs to build on each others' learning and work towards specifying consistent requirements in a consistent way.

Developers of standards and network codes

Design development work from the MASC project will provide a valuable input into the process of making any appropriate changes or amendments to the various Industry operating practises required in order to fully benefit from a modular solution.

Renewable Generation Developers

A significant number of the new substations planned for GB are to allow the connection of new renewables. Renewable generation developers will be a key target audience for the outputs from MASC. This will ensure that the interfaces etc between the new development and the new substation can be properly coordinated.

Suppliers

For suppliers to offer commercial products meeting the GB network operators' needs, they need to receive specific requirements communicated in a clear way. Learning in the form of refined requirements to be used in the procurement process is therefore of significant interest to suppliers. This will be validated from the MASC operational period to monitor and evaluate the products' performance under a range of operating conditions.

Government and Regulators

While not a primary target audience for learning, a general overview of the outcomes from the MASC project, in particular the development of standards will be of interest to policy makers and Ofgem because validated results regarding the performance and impacts of modular substations will give these groups improved confidence to approve plans put forward by network operators.

IPR Arrangements

It is our intention that the work undertaken using NIC funding will adhere to the NIC default

Knowledge dissemination continued

IPR arrangements. However, this will be subject to confirmation depending upon the final outcome of the commercial negotiations with equipment suppliers, project partners and other stakeholders. In all negotiations SHE Transmission will strive for maximum availability of the Project work for dissemination and sharing purposes.

Section 6: Project Readiness

This section should be between 5 and 8 pages.

Requested level of protection require against cost over-runs (%):
0%

Requested level of protection against Direct Benefits that they wish to apply for (%):
Default 50%

6.1 Project Readiness Summary

Overall the MASC NIC project is poised to start, with all of the key stakeholders ready to participate, the resources and project framework in place, and the project planning at an advanced stage.

The MASC project will be delivered within SSE's Major Projects Governance Framework (tailored for Innovation projects), with the Innovation Steering Board as the Project Board and Stewart Reid (Future Networks Manager) as the Project Director.

The following appendices support the Project Readiness of MASC:

Appendix 1: Full Submission Spreadsheet;

Appendix 4: Examples of Previous Deployment;

Appendix 5: Work Programme;

Appendix 7: Business Case Supplementary Information;

Appendix 8: Risk Register and Contingency Plan;

Appendix 9: Organogram;

Appendix 10: Funding Commentary

6.2 Project Start

The MASC project is ready to commence; the NIC project has already passed Gates 0 and 1 as defined in the company's governance procedures, in early preparation for the delivery of the project. Key roles within the delivery team have already been filled and we are prepared for the transition to full project delivery upon award of NIC funding.

The MASC project has been prepared with support received at all levels of SHE Transmission's management hierarchy (see Appendix 9 for a description of this).

The project board includes members of the senior management team including Mark Mathieson (Managing Director of Networks) and David Gardner (Director of Transmission), each of whom is actively committed to the successful delivery of the project.

The project team includes:

- Project Director: Stewart Reid (Future Networks Manager)
- Project Development & Stakeholder Engagement: Frank Clifton
- Project Manager: Fiona Irwin
- Stakeholder Engagement: Avril Vera-Leon
- Transmission Operations : Peter Dale (Director of Transmission Operations)
- Engineering: Andrew Scott (Head of Engineering)
- Connections / Commercial : Kenny Stott

- Recruitment & Training Lead: Matthew Allan
- Learning & Dissemination Lead: Sorcha Schnittger
- Legal: Debbie Harding
- Regulation: Jen Carter
- Finance: Steve Kennedy/ Davina Button
- Procurement & Commercial: Carl Lappin/ Hamish Myles

The availability of the above resources to start in January 2015 has been agreed. The project team will primarily be based in SHE Transmission's offices in Perth and Glasgow. Based on this, there are no concerns associated with starting the project on schedule.

6.3 Cost Estimates

The following process has been adopted to ensure that the cost estimates included in this proposal are robust:

- The functional requirements were defined with input from project partners; this consists of internal and external stakeholders, including engagement with a wide range of supply chain partners.
- Each element of the technical and non-technical requirements have been based on learning captured from SHE Transmission's previous experience, and on external quotations.

Note that the money sought from the NIC for this project is to cover **only the additional costs and risk of deploying this technology for the first time on the GB network**. The remaining costs i.e. costs associated with that of a conventional connection, are being recovered in accordance with the industry standard charging arrangements.

SHE Transmission has created an initial but detailed requirements specification based on the utilisation of traditional substation equipment. This specification has been used as the basis for cost estimates for MASC, with contractor costs estimated using information available through SHE Transmission's Procurement team. This team use competitive processes and framework contracting to ensure value for money.

In order to develop the MASC project SHE Transmission has undertaken extensive discussion with the supply chain; this consists of equipment manufacturers, civil contractors and designers. Early supply chain engagement has shown that there are a number of potential suppliers of equipment necessary to meet the high-level objectives of the project. Clarification on costs for a generic MASC project was also sought to test robustness of cost estimates; estimates given by manufacturers have been used as a basis upon which to estimate the total cost of a 60-90MVA 132/33kV substation, which is the capacity that will be used for the project.

For the labour elements of the project the established SHE Transmission rates for staff time have been used. All other cost elements have been assumed based on discussions with manufacturers and historic experience around other innovation type projects.

6.4 Minimising cost overruns

The MASC project costs fall into three main categories:

Resourcing: This factors in SHE Transmission internal resource and support from external organisations to develop the new, innovative functional specification and develop any new operational practises required to implement the new approach.

Internal support will be closely monitored ensuring optimisation of skilled personnel. External support will be capped, to ensure that there is no overspend.

Equipment & mitigation costs: This covers additional costs associated with one-off, first time procurement. Manufacturers will have new challenges associated with supplying their products into the GB market for the first time. An element of adaption and modification to the equipment may be required to ensure it is suitable for the GB market.

A programme of supplier engagement will help to develop an understanding of issues and costs that equipment adaptations will entail. An appropriate competitive exercise will be undertaken to ensure best value when procuring the equipment. The most appropriate strategy will be selected prior to the project commencing and will build upon early supply chain engagement.

Costs estimates have also be derived to include unpredictable factors, such as additional support for inspection of equipment to ensure it is performing as anticipated

Appropriate commercial arrangements will be put in place with the selected equipment supplier to make sure that the equipment meets the project objectives. These arrangements may include additional maintenance support or enhanced warranties.

IT: This includes the installation of monitoring and control equipment, in order to ensure that the MASC substation is performing as anticipated. Engagement with key stakeholders to understand concerns, whilst investigating potential challenges MASC will encounter will ensure an effective monitoring package.

6.5 Benefits Estimates

The following process has been adopted to estimate the benefits of the project:

- Initial benefits were identified by the MASC project team.
- These initial benefits were peer-reviewed by TNEI (consultant for the MASC project) to produce a revised, independent view of potential benefits.
- The amended benefits were then validated by members of the supply chain.
- Given that the benefits are comprised of both direct and indirect benefits, they are considered accurate to within +/-25%.
- In general a very conservative view has been taken in estimating the potential benefits that the MASC will enable. However, even in the worst-case scenario of maximum cost and minimum benefits, the project still has a strong business case.

6.6 Minimising shortfalls in direct benefits

The MASC project seeks to secure funding for the **additional cost of installing a modular substation for the first time**.

The cost of providing the conventional solution is being funded via the existing industry arrangements for a new connection. The cost of this project has been identified as direct benefits in the Full Submission Spreadsheet (Appendix 1).

6.7 Quality Plan

All information contained in this proposal (including Appendices) has been subject to a rigorous process to assure validity and accuracy which includes peer review; external expert review; and internal management review.

Project Reviews

A review meeting is held to examine the current status of a project prior to any significant cost commitment such as equipment procurement. Concerns must be satisfied before a project team may make a large purchase; any concerns which cannot be satisfied follow a strict escalation procedure, with Ofgem informed if this is the next appropriate action.

6.8 Process for Suspending the Project

The project is subject to the company's gated project management process, and at each gate the project's feasibility and risks will be reviewed before a project may proceed to the its next steps or "gate".

Furthermore, regular risk review workshops exist to escalate a significant risk or issue that requires a decision on the feasibility of the project. Any resulting proposed change to the project or request to suspend the project would then be submitted to Ofgem for approval.

6.9 Cross-Sector

This project is not part of a cross-sector project.

6.10 Project Plan

A detailed work programme plan can be found in Appendix 5, and an overview is provided below:

The MASC project delivery will be managed using SHE Transmission's Major Projects Governance Framework (a mandatory requirement for projects of this size within SHE Transmission).

The process has five phases with 'gate keeping' as the project moves through the phases. The purpose of the gates is to ensure transparency, scrutiny and appropriate approval on project development and required deliverables. Clarity on project risks as well as benefits, will assist with business decision making. An example of SHE Transmission's gated management process can be seen on Figure 6.a

Electricity Network Innovation Competition Full Submission Proforma

Project Readiness continued

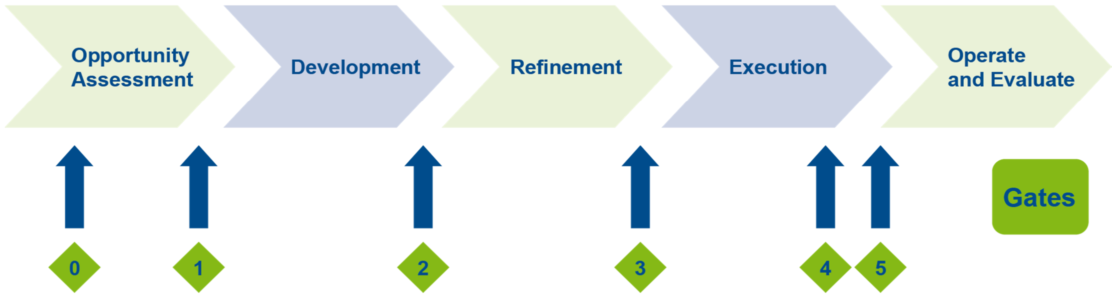

Figure 6.a Example of SHE Transmission's gated management process for innovation projects.

Phase 1: Opportunity Assessment

The phase was completed and the gate passed, prior to submitting the NIA funding request for the MASC trial.

Deliverables: Business Strategy and Regulatory Fit Analysis, Cost Estimate Classification 0, Business Case, Conceptual Design and Signed-off ISP for the NIC.

Phase 2: Development

The MASC project is currently within this phase.

Deliverables: Preliminary Site Feasibility Study, Cost Estimate Classification 1, Business Case, Project Development Plan, Governance, Development Resource Review, Project Safety Health and Environment Review, Environmental Requirements, Design Development, Technology Overview, Risk Management and Signed-off NIC Full submission document

Phase 3: Refinement (Design)

In this phase the design of the MASC project will be fully developed.

Deliverables: Health and Safety Plan, Environmental Requirements, Cost Estimate Classification 2, Business Case, Project Development, Contract and Procurement Strategy, Planning Permission and Land Options, Governance, Refinement Resource Review, Detailed Site Feasibility, Design Development Document, Risk Management Plan, Quality Management and Lessons Learned

Phase 4: Execution (Build)

In this phase the MASC project will be constructed and commissioned.

Deliverables: Health and Safety Plan, Cost Estimate Classification 3, Business Case, Operation Plan, Resource Review, Risk Management Plan, Quality Management, Lessons Learned and Testing & Commissioning Plan

Phase 5: Operate and Evaluate

Two years of operations and monitoring will be undertaken using the NIC funding.

Deliverables: Health and Safety Plan, Resource Review, Quality Plan, Project Handover Plan, Lessons Learned and Concluding Report

Project Readiness continued

Project Gates

Six gates exist as shown in Figure 6.10, where project development, definition and key deliverables are assessed to ensure the project benefits and opportunities are being fully exploited and project risks are understood, mitigated and controlled.

Work Packages

Funding secured under the MASC NIC bid will facilitate all of the necessary work to evaluate and promote the solution into 'business as usual' whilst sharing the learning and knowledge amongst the other network licensees. There are six key work packages associated with the MASC NIC bid, to ensure that the full potential is achieved, as description follows;

- WP1 – Project Management: phased over the duration of the project and associated with the internal resources required to deliver successful analysis, proactive engagement from stakeholders and dissemination of learning to the industry;
- WP2 – Detailed Requirements Scoping: phased over the first two years, during which time the civil, structural, safety, operational and future versatility of the MASC chosen solution will be identified and developed in detail. This will include beginning to develop detailed strategies to integrate into 'business as usual';
- WP3 – Construction: phased between years 2-3, associated with the period that the MASC solution will be fabricated in the factory, delivered, installed and commissioned onto the system. Within this work package are the elements associated with seeking additional planning consent, equipment specification, and reliability and mitigation measures. This will include the full construction and commissioning of a MASC based substation on site.
- WP4 – Operation: starts in year 3 and continues to year 4, on-site monitoring and evaluation of the MASC innovation to ensure that is delivering as expected. This will allow validation of the MASC benefits to ensure that they are properly understood and realised throughout the business.
- WP5 – Monitoring and Evaluation: starts in year 3 and continues to year 4, during this time the information collected from the monitoring equipment will be analysed, conclusions drawn, if necessary additional monitoring undertaken and opinions based upon findings formulated.
- WP6 – Knowledge Dissemination: phased over the duration of the project and associated with the facilitating knowledge sharing both internally and externally, and working to integrate MASC into "business-as-usual" processes.

Each work package has been further subdivided into specific tasks. A lead will be a pointed to each task; they will be responsible of the delivery of the outputs and will be coordinated by the project manager.

6.12 Project Programme

The outline work programme is included in Appendix 5. This programme will allow both the MASC and conventional alternatives to be designed and developed in parallel in order to ensure that SHE Transmission meets the anticipated connection date.

6.12 Risk Management and Contingency Planning

The project incorporates a number of innovative new elements ranging from new technology to new operational practises and procedures. Consequently, there is a degree of risk and uncertainty that needs to be managed. The work breakdown structure and the utilisation of SHE Transmission's well established "Large Capital Projects" Governance Framework will ensure that any risks are identified and monitored with appropriate mitigations in place.

The risk register and contingency plan are included in Appendix 8. These set out the primary risks for the project and the mitigations and contingencies that will be put in place to manage these risks.

Section 7: Regulatory issues

This section should be between 1 and 3 pages.

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

Derogations and requests to change regulatory arrangements

The MASC project is within the scope of the regulations and no derogations, licence consents or changes to regulatory changes are anticipated to be required.

The functional specification will make adherence to all relevant legislation mandatory, including:

- Electricity Safety, Quality and Continuity Regulations 2002;
- Electricity at Work Regulations 1989;
- Electricity Supply Regulations 1988;
- Construction (Design and Management) Regulation 2007; and
- System Operator Transmission Owner Code 2004.

Currently, established industry operating procedures and guidelines are based on traditional, air-insulated (AIS) or gas-insulated (GIS) substations. MASC substations use the same components as traditional substations, however the layout and design will be significantly different.

To this end, MASC will create learning which challenges historic approaches to Health, Safety and Environment guidelines although it will be ensured that that the new design philosophy strictly adheres to Regulations.

MASC may also inform the STC (System Operator Transmission Owner Code 2004)[8] and influence future developments.

A proportion of NIC funding will be used to identify areas within current regulations which may need to be addressed to facilitate the full benefits of MASC substations. The funding would also enable the creation of an action plan to progress any necessary modifications.

Some of the NIC funding will also be safeguarded for additional monitoring and evaluation, knowledge dissemination and mitigation for safety and operational procedures. This will ensure that key points concerning regulatory compliance is identified and made available for industry-wide learning.

Electricity Network Innovation Competition Full Submission Proforma

Section 8: Customer impacts

This section should be between 2 and 4 pages.

For this project, MASC will be used to deploy and demonstrate a 33kV-132kV substation which connects a new, renewable generation development to the transmission network. This NIC funding request seeks financial support to cover the incremental costs of implementing MASC for the first time. SHE Transmission's intention is to trial the method on a planned connection project in Scotland. In order to ensure knowledge capture and learning is delivered from the outset, MASC will be deployed on a project that SHE Transmission has already committed to deliver. SHE Transmission will be under contractual obligations to deliver the project within time and cost agreements made within its connection offer to the developer. As the connection must proceed regardless of NIC funding awards being granted, funding for the general delivery of the project will be held in a separate bank account as indicated in the NIC Governance Document. In the event that NIC funding is not awarded, the connection will still proceed, using conventional equipment to ensure the agreed connection date is achieved.

8.1 MASC impact on transmission customers

The learning from MASC will be applicable to a wide range of substation projects. This could be either a new generation connection or an infrastructure projects. While MASC can be applied across a network operator's substation portfolio, the project will select a developer seeking a non-firm renewables connection. This is an "electrically" simple type of connection probably in remote location which will allow us to maximise the benefits from a MASC connection whilst minimising network risk. Due to the nature of this project, no interaction at all is required with end consumers. The learning from the MASC project is expected to demonstrate a reduction in cost and construction time on substation construction and associated costs, which will be passed to transmission customers, as described in Section 4.

8.2 MASC impact on generation developers

The learning from the MASC project will be beneficial to renewable developers by reducing the cost of future transmission connections. This is an area where the MASC approach is likely to be able to be used to its full advantage i.e. new sites, relatively simple electrical networks in remote locations. Wider transmission customers will benefit from a reduction in any costs associated with the new connection which are socialised in accordance with the CUSC.

For the trial deployment, SHE Transmission will select a project seeking a connection for a renewable energy generation plant such as a 60-90MVA wind farm on a non-firm basis. In order to ensure that that the project is delivered within the MASC project timeframes, SHE Transmission will identify all committed projects which have full planning consent and are seeking connection in 2017 or earlier.

Electricity Network Innovation Competition Full Submission Proforma

Section 9: Successful Delivery Reward Criteria

This section should be between 2 and 5 pages.

The following section describes the Successful Delivery Reward Criteria for the project, the completion of which are key milestones and indicators of the overall success of the MASC project. Progress against these criteria will be monitored and reported on during project delivery. The following section describes the Successful Delivery Reward Criteria for the project, the completion of which are key milestones and indicators of the overall success of the MASC project. Progress against these criteria will be monitored and reported on during project delivery.

Criterion 9.1: Stakeholder engagement

A key milestone of MASC's success involves the outputs of engagement with key stakeholders groups, to potentially include:

- internal contact with SHE Transmission business areas;
- external contact and other License holders:
- external dialogue with manufacturer and broader supply chain; and
- external stakeholders such planning and other statutory bodies.

Work undertaken within this criterion will seek to inform the development of the technical and functional aspects of the MASC substation.

Evidence: A report detailing the outputs from stakeholder engagement activities and their impact on MASC's functional specification requirements will be published by 30th July 2015.

Criterion 9.2: MASC substation detailed design

The publication of the final, functional requirement document for the MASC project will require the identification of new equipment and associated requirements of operation and maintenance. The NIC funding will also support evaluation of new civil engineering practices and advances in aesthetics and environment that could factor into the final functional specification.

Evidence: A report will be published by 15th January 2016. This will contain identification of the key innovations that have been incorporated into the final technical specification.

Criterion 9.3: Knowledge capture from off-site construction

At this stage, MASC components will be manufactured and tested in a factory environment. This stage offers invaluable opportunities to evaluate individual components, protection and control systems. Comparison between MASC off-site construction and commission testing (in a clean, controlled environment) with conventional on-site construction processes will be collated.

Evidence: Written analysis of the progress towards complete system testing achieved during the factory stage and identification of cost savings will be completed by 31st of October 2016.

Successful Delivery Reward Criteria continued

Criterion 9.4: Knowledge capture from on-site installation

At this stage, the substation will be transported to site, with essential on-site construction completed. Key learning from this stage will validate outputs from stakeholder engagement.

Evidence: the MASC project team will produce an analysis document which provides a clear assessment of the benefits of the project's approach in comparison to conventional methodology in installation of an air-insulated substation, by 30th June 2017.

Criterion 9.5: Analysis of MASC on-site commission and energisation

NIC funding will be used where appropriate to deliver validatory on-site re-testing and commissioning when the substation is installed and energised. Verification of on-site commissioning and energisation will also take place. This will be compared with the outputs from the factory commissioning tests.

Evidence: A full report detailing the outputs and knowledge capture will be published by 29th September 2017. This will include learning on the substation's behaviour during, and following, energisation.

Criterion 9.6: Operational Learning

The MASC solution is anticipated to challenge current operational and maintenance practices. Knowledge captured throughout a period of MASC operation will inform and validate key operational and maintenance theories.

Evidence: The MASC project team will publish a paper which summarises ways in which MASC solution elements challenge present day procedures. This paper will include mitigations against said challenges and highlight possible improvements. While the initial document will be available by 30 June 2018, this paper may be modified if new information is deemed relevant.

Criterion 9.7: MASC Performance Monitoring and Evaluation

Monitoring will be ongoing throughout the project's lifecycle. At this stage, valuable knowledge concerned with factory, transportation, installation, and operational monitoring will be collated.

Evidence: A summary report of the monitoring undertaken and the recommendations drawn out from analysis will be published by 18th of December 2018.

Criterion 9.8: Project Closedown Report

At the end of the project, full evaluation and key learning points will be considered for inclusion in a comprehensive project closedown process. This will include learning gathered from knowledge events and the progress of the MASC substation during operation.

Evidence: A detailed closedown report will be delivered by the 28th June 2019.

Section 10: List of Appendices

Appendix Number	Title
1	Full Submission Spreadsheet
2	Letters of Support from Supply Chain
3	Technical Description of Substations
4	Examples of Previous Deployment
5	Work Programme
6	Market Assessment
7	Business Case Supplementary Information including Benefits Summary
8	Risk Register and Contingency Plan
9	SHE Transmission Organogram
10	Funding Commentary
11	Maps and Network Diagrams
12	Reference Notes
13	Progress report on NIA_SHET_0013 project
14	Resource Plan

SSEN01 – MASC - Appendices

APPENDIX 1 – Full Submission Spreadsheet

The complete Full Submission Spreadsheet was submitted separately via the FTP site. The table below summarises the Outstanding Funding request;

Outstanding Funding required (£k)							
	2014/15	2015/16	2016/17	2017/18	2018/19	2019 /20	**Total**
Labour	38,166.30	196,622.01	298,802.87	388,209.60	314,362.10	-	1,236,162.88
Equipment	8,280.00	339,611.40	290,235.47	79,891.11	84,396.06	-	802,414.04
Contractors	32,400.00	174,445.20	114,793.20	138,083.40	95,581.08	-	555,302.88
IT	6,750.00	29,692.80	58,831.52	70,521.17	54,399.87	-	220,195.35
IPR Costs	-	-	-	-	-	-	-
Travel & Expenses	15,300.00	57,065.85	32,046.44	7,890.48	10,168.20	-	122,470.97
Payments to users & Contingency	-	-	-	-	-	-	-
Decommissioning	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-
Total	100,896.30	797,437.26	794,709.50	684,595.75	558,907.31	-	2,936,546.12

NIC FUNDING REQUEST	**£**	**2,835,044.02**

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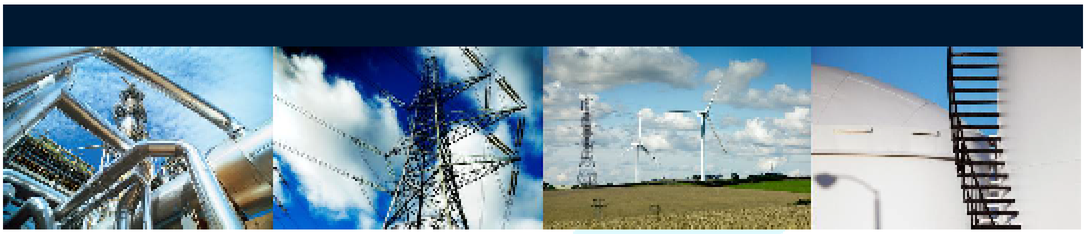
[redacted]

[redacted]



enterprise with energy

Appendix 3 - Technical Description of a Substation

Project Code/Version No: SSEENO2/1.0

To:	Frank Clifton	Company:	SSE PG
From:	Alan Mason	Project Reference:	9328-03-R1 MASC -NIC -Bid
Date:	20-Jul-14		

Part of the Petrofac Group

enterprise with energy

The GB Transmission Grid

The electricity network in GB is made up of a transmission and distribution systems.

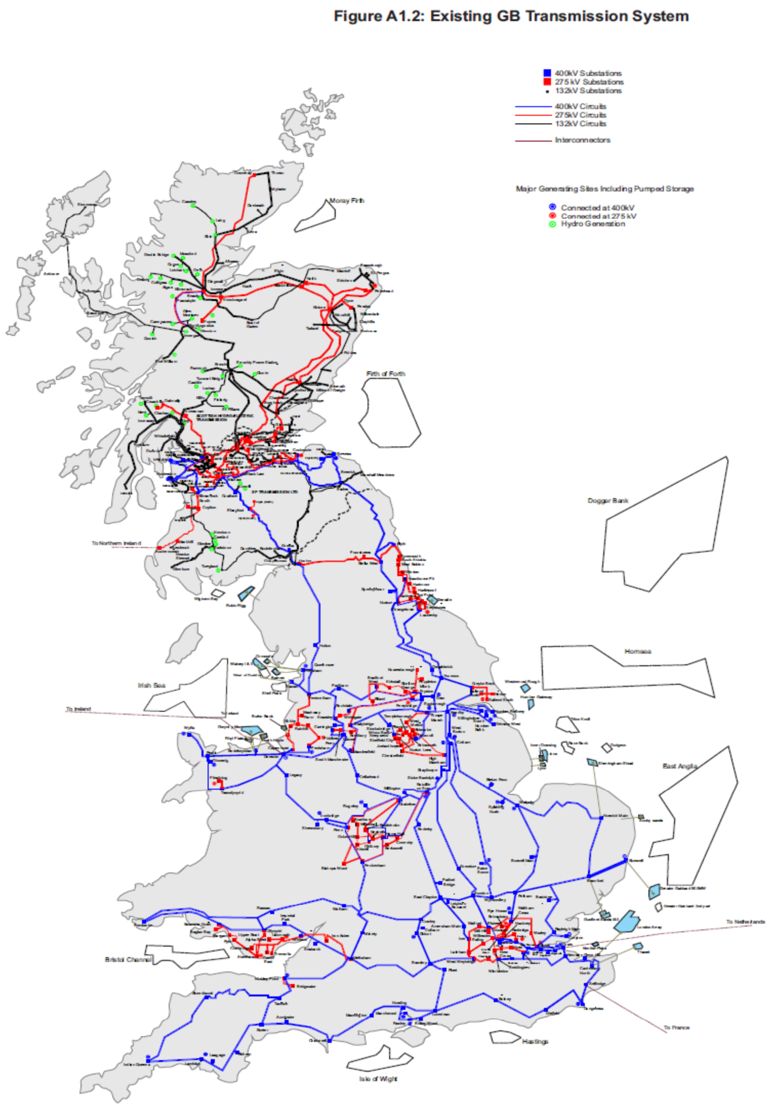


Figure 1. Map of the GB Transmission System[1] (Figure A1.2 from Appendix A1 – Geographic System Maps of the Current Electricity Ten Year Statement, National Grid April 2014)

The transmission network - often referred to as the grid - is responsible for the bulk transport of large amounts of electricity from generators to distribution supply points. The transmission grid covers the whole of the country stretching from Caithness in the north of Scotland to Cornwall in the south west of England, as shown in Figure 1.

1 http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Electricity-ten-year-statement/Current-statement/

The electricity from the transmission grid is transferred to the regional distribution networks at Grid Supply Points where it is then distributed to industrial and domestic users.

In England and Wales the transmission grid operates at 400,000 Volts (400kV) and 275,000 Volts (275kV). In Scotland, networks operating at 132,000 Volts (132kV) are also classed as transmission. High voltage systems are expensive to construct and operate, therefore while bulk transport of electricity is done at transmission level; the distribution of energy to homes and businesses is generally carried out at a lower voltage. The voltage level for distribution is usually 132,000 Volts (132kV) (in England and Wales only) 33,000 Volts (33kV) and 11,000 Volts (11kV) in GB.

A simple analogy of the GB electrical network is to compare the grid to the GB road network, with motorways representing the transmission network and the A and B roads representing the distribution network. Meanwhile, motorway junctions can be thought of as substations. Substations are the "junctions" which connect electricity generation to the network. Substations also serve to move electricity from the transmission, network to the distribution network, where it can then be delivered to homes and businesses.

Design of Transmission Substations

A substation is a junction at which electrical energy is allowed to;

- enter the transmission network from generation plants;
- leave the network at Grid Supply Points to enable it to reach the end customer through the distribution network; or
- a meeting place of several electrical circuits where the energy can be redistributed or shared out more evenly as it moves onto its end destination.

In the first two instances above, electricity leaves the transmission system. This requires the use of a transformer to increase or reduce the voltage levels. Figure 2 shows a very simplistic electrical components layout which makes up a transmission substation bay and includes a transformer.

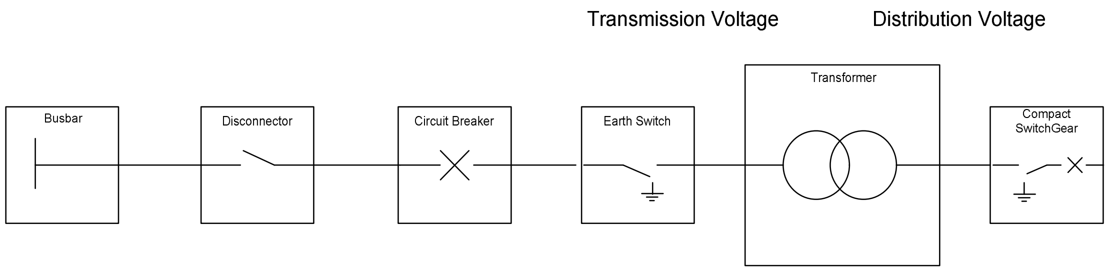


Figure 2 – Typical components of a substation bay with a transformer

The main elements of a transmission substation bay are described in Figure 3 below.

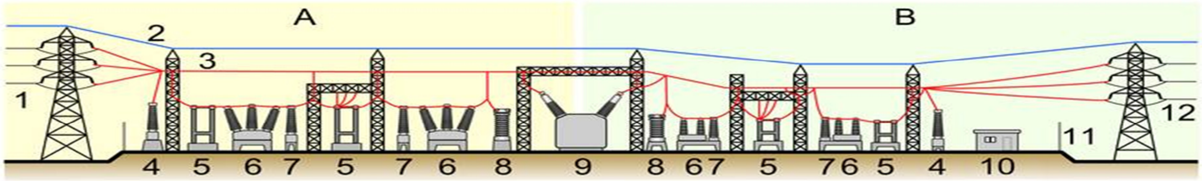


Figure 3 - Example diagram of a traditional, air-insulated transmission substation

1. Primary power lines. 2. Earth wire. 3. Overhead lines. 4. Transformer for measurement. 5. Disconnect switch. 6. Circuit breaker. 7. Current transformer. 8. Lightning arrester. 9. Power transformer. 10. Control building. 11. Security fence. 12. Secondary power lines.

Circuit Breaker or Switchgear

A circuit breaker, which is also commonly referred to as switchgear, is a reusable fuse. In other words, it interrupts or breaks the electrical circuit and stops the flow of electrical energy. It is identical in principle to a household fuse which can be found in on main fuse board, but a much larger in scale and with the additional ability of being operated remotely.

Transformer

A transformer can be thought of as a device which takes in one voltage and either increases or decreases it down for export. Transformers work using a principle called electromagnetic induction. This requires the use of a solid core made from a magnetic material, and two coils, both of which are wrapped round the core.

One coil carries the incoming electrical energy and the other coil carries the outgoing electrical energy. The core and coils work together to produce and electrical energy entering and leaving the transformer. There are no moving parts in the transformer but the process produces heat. A cooling system is used to keep the unit from overheating.

There are a number of ways of achieving this, including the circulation of a liquid, such as synthetic oil, around the operating core and other components. Image 1 shows a basic oil- and air-cooled transformer, where oil circulates around the core using convection. It flows into another component (the radiator fins), where the oil can then be cooled using natural air flow. Electric fans can be added to the radiators to force air over the fins in larger transmission transformers.

Image 1 – Typical Air-Insulated Transformer

Disconnectors and Earth Switches

Disconnectors and earth switches can be thought of as a secondary protection measures to isolate components of the network so that essential maintenance or inspection can be carried out. Disconnectors are generally operated after the circuit breaker has been activated (which is the primary method of stopping power flow in the network) An earth switch is then subsequently applied which allows any residual current to flow safely to earth prior to anyone attempting to work on the equipment.

Bus Bars

Bar-bars are cylindrical metal tubes which carry the electrical energy between the different substation equipment. Within a substation these are generally located at a high level, and are supported by concrete structures.

Measurement Transformers

In order to maintain a secure supply of energy and to allow the safe operation of the equipment, measurement transformers are located at strategic points within the system. These devices generally known as voltage transformers (VTs) or current transformers (CTs) and are key to the operation of a substation.

Control and Protection Equipment

'Protection and control equipment' (P&C) is a general term used to describe all of the measurement and control equipment required to operate the substation. This will consist of a number of relays and other devices which will be set to the required parameters to protect the plant in the event of a fault.

The use of P&C is not only ensures the safety of the equipment within the substation, but also works to minimise disruption to electricity supply. P&C may include Supervisory Control and Data Acquisition (SCADA) or Real Time System equipment which will sent information and control instructions to and from any centralised control facility. P&C equipment is generally housed in panels. Image 2 below shows a typical panel. The work required for connection and commissioning of the control and protection system in a substation is a significant contributor to construction times.

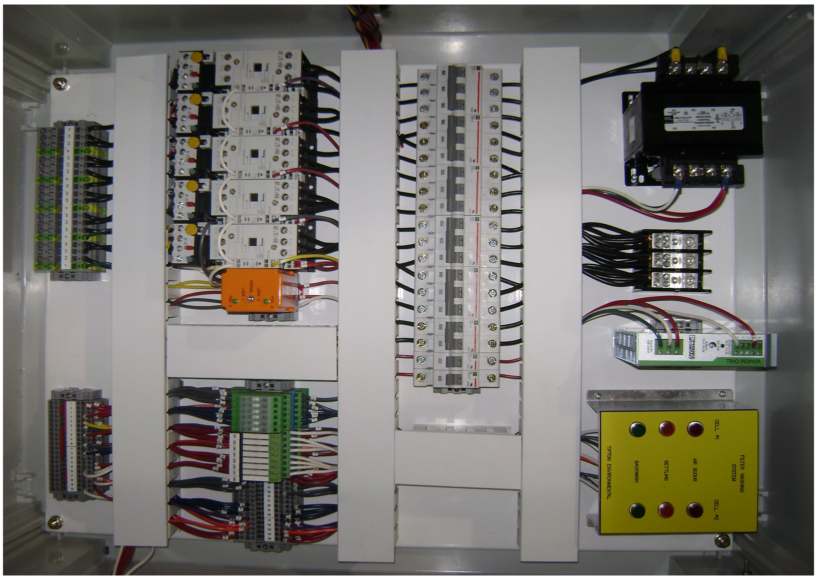


Image 2 - Typical Control and Protection Panel

P&C equipment which is very much the “brain” of the substation as it enables the energy to be monitored; if a fault is detected then an automatic sequence is initiated to protect the equipment. In many substations, remote operation from a transmission operator’s control room is possible. Advancements in this equipment have enabled larger substations to operate entirely remotely. Figure 4 below highlights some of the necessary elements to the protection and control equipment.

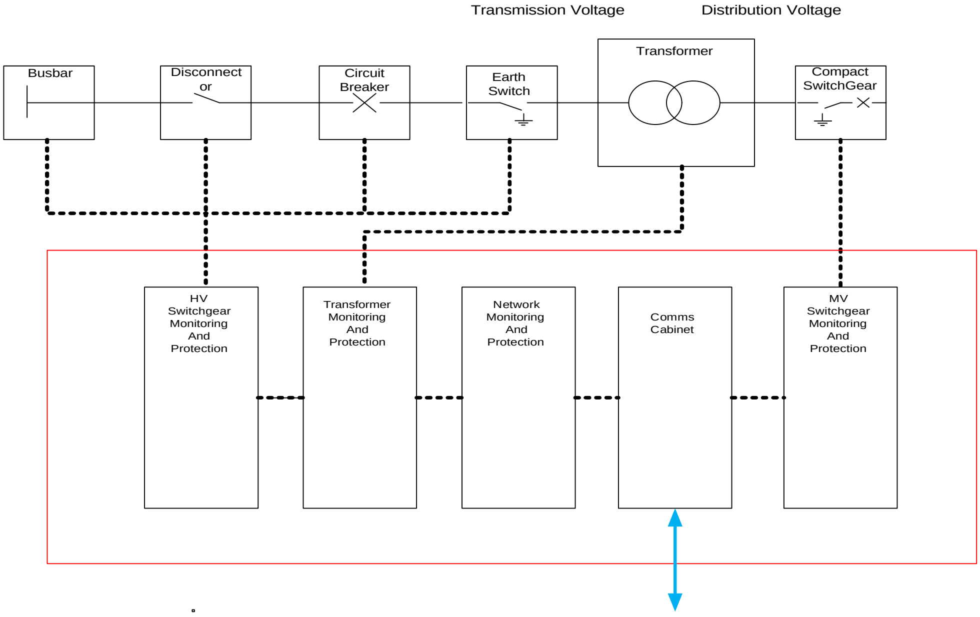


Figure 4 - Simple diagram including Protection and Control Equipment

Different Types of Substations

There are two generic types of transmission substations which are differentiated based upon their electrical insulation medium. Insulation ensures that electrical energy stays within its correct metallic conductor and therefore moves efficiently through the network. Air is the primary electrical insulation medium, but it requires electrical equipment components to be placed a significant distance apart, therefore has a large geographical footprint.

Image 3, left, shows an aerial photograph of a substation with two transformers and a low voltage air insulated substation (AIS). The white van next to the control building at the top left gives some idea of the scale.

Image 3 – Aerial photograph of two transformers and a low voltage AIS substation

Through design innovation a substation solution using inert gas as an insulation medium was developed in the early 1980s, as an alternative to AIS. A gas-insulated substation (GIS) uses Sulphur Hexafluoride (SF_6) as the insulation medium, which is enclosed within a metal casing. This allows the circuit breaker, disconnectors, earth switches and bus-bar to be placed much closure together. A GIS solution requires a smaller footprint, but is expensive in comparison to AIS and there are environmental challenges related to use of $SF_{6.}$ Image 4 depicts an example of a GIS solution, below.

Image 4 – Example of a GIS Substation

Image 4 shows a selection of substation components, which have been housed within a building in a very compact way. This is relatively common in locations with space restraints. However, the transformer is still placed outside of the GIS building.

Aspirations for a Modular Substation

Today approximately 85% of generation connection applications are from a renewable source and the majority could be connected into the network via a simple solution, as shown in Figure 5 below..

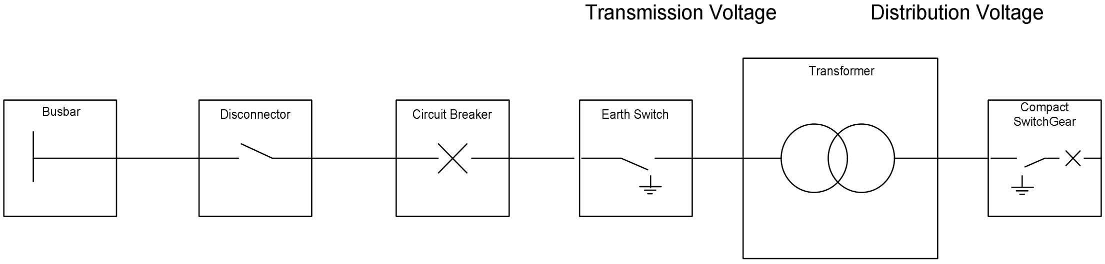


Figure 5 – Typical Components of a transmission substation bay with a transformer

With the recent and significant shift towards renewables, a number of key parameters associated with the generation source have changed. These changes could challenge current methodology of transmission substation bay design. In searching for ways to improve substation construction and design methodology, it is useful to evaluate and actively seek out innovations which align better with these key parameters, whilst keeping mindful of maintenance and operation processes.

The renewable generation key parameters are outlined below;

- ⇒ an intermittent generation production pattern;
- ⇒ generation projects situated in very remote locations;
- ⇒ an operational life of 25 years;
- ⇒ often extended within 5-10 years of first power export; and
- ⇒ repowered after 25 years (assumption is with larger units).

It is the aspiration to work with a manufacturer to produce a transmission substation solution that can be pre-assembled in a factory, as much as feasibly possible. The solution can then be tested and transported to site and efficiently installed onto the network. Several manufacturers presently offer solutions for mobile distribution substation bays, which are temporarily connected into the network. Image 5 displays a mobile substation bay containing a 45/15kV transformer (20kVA) built by Alstom for Iberdrola (for their Spanish network).

Image 5 - Mobile distribution substation bay (built by Alstom for Iberdrola)

There are challenges to be overcome to progress the mobile distribution substation bay in Image 5, into a suitable solution at a transmission level of 132kV and a transformer that is sized correctly. However there are significant positives with such a containerised solution which can be summarised as follows;

- ⇒ increased number of components connected together at the factory, therefore:
  - § Labour resource close to the factory, reducing associated on-site overheads;
  - § Equipment fabricated in a controlled environment therefore de-risking associated contamination type faults; and
  - § Testing within the factory, test equipment available with reliable power sources, good availability of skilled commissioning resource, significant time savings if a fault is identified as it's within the factory therefore better access and time for correction.
- ⇒ The containerised nature of the electrical equipment, may enable maintenance activities to align with the intermittent pattern of generation, assuming maintenance is required;
- ⇒ Seeking consents for the electric substation may be a smoother process as the modular solution requires less land take, is less aesthetically intrusive, reduces associated temporary working areas, site welfare facilities and significantly lowers the volume of vehicular activity therefore much less of an environmental nuisance;
- ⇒ Significantly reduces the site civil requires, the number of personnel require on-site during installation and commissioning phases, compresses the site time which are all very significant factors in remote locations;
- ⇒ A modular system lends itself to the option of complete removal after the generator stops producing, it may also be feasible to redeploy the modular substation;
- ⇒ If the generator expands a modular substation should facilitate additional bays easily or potentially an exchange of a transformer for a higher rated unit;

Comparisons between AIS, GIS and a Modular Substation

When designing a new transmission substation there are a number of factors which are taken into consideration; overall cost and operability are very high on the list.

The development of a modular substation solution will potentially increase the design option portfolio. Below Table 1 shows a summary of the comparisons between AIS, GIS and the aspirations around modular substation solutions.

	AIS	GIS	Modular Substation
The range of substation application	Generation Connections, Grid Demand Points, any other substation type	Generation Connections, Grid Demand Points, any other substation type	Initially single bay generation connection; solutions needs to be evaluated prior to being rolled out

			elsewhere
Size of land take footprint	The largest footprint as the insulation medium is air	Approximately 55% smaller then an AIS equivalent	Anticipated to be 65-70% smaller then an AIS equivalent
Consenting / Environmental Challenges	Requires a larger land take therefore environmental effects a larger area and high environmental nuisance with vehicle volumes	The insulation medium SF_6 is on the list of gasses which requires monitoring and stringent controls as it's an environmental pollutant.	It is likely that SF_6 will be insulation medium but in a smaller volume then a similar GIS solution. Vehicle movements a kept to a minimum.
Description of the installation phase	Electrical equipment shipped individual to site, requires storage, prior to on-site assemble and commissioning	Electrical equipment shipped individual to site, requires storage, prior to on-site assemble and commissioning	Electrical Equipment assembled in the factory, tested and shipped ready for connection into the network
Duration of the installation phase	6-8 months on-site	6-8 months on-site	1-2 months on-site
Location of the key workforce	The electrical component factory, the design house facility and on-site for the duration of the installation and commissioning	The electrical component factory, the design house facility and on-site for the duration of the installation and commissioning	The factory / design house, a reduction in resource requirement on-site for installation and commissioning
Maintenance / Operational Phase	Well understood with policies /procedures in place.	Well understood with policies /procedures in place.	Challenges present operational practises, will require new policies and procedures.

Table 1 - Comparison between AIS, GIS and Modular Substation Solution

TNEI Services Ltd			
Bainbridge House 86 – 90 London Road **Manchester** M1 2PW Tel: +44 (0) 161 233 4800 Fax: +44 (0) 161 233 4801	Milburn House Dean Street **Newcastle Upon Tyne** NE1 1LE Tel: +44 (0) 191 211 1400 Fax: +44 (0) 191 211 1432	Queens House 19 St Vincent Place **Glasgow** G1 2DT United Kingdom Tel : 0141 428 3180	Chester House 76-86 Chertsey Road **Woking** Surrey GU21 5BJ United Kingdom

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Appendix Four - Examples of Previous Deployment

Brief overview of the range of projects internationally where a modular or mobile solution has been implemented. There are other installations but those shown below are an indicative sample.

Modular Substations

Project Information	Equipment Supplied	Supplier	Details
Design, build and install modular substation for Grand Bahamas Power (GBP)	69/12kV 10 MVA modular substation	ModPower	GBP's Shipcare Facility required the design and installation of a new power station. With an eight month timeline, the traditional approach to building an electrical substation was not an option. Instead, GBP chose a modular power system because of its expedited timeline, flexibility and scalability.
Design, build and install modular substation for BorgWarner (Rail)	115/15kV 10 MVA modular substation	ModPower	BorgWarner required the design and installation of a modular substation within a six month timeframe, on a tight budget and with minimal onsite labor costs.
Design, build and install modular substation for Walgreens (Pharmaceuticals)	115/12.5kV modular substation	ModPower	Walgreens required the design and installation of a modular substation to support the operation of a central warehouse facility. It was essential for the modular substations to be energized within six months.
KeySpan Energy (now National Grid), USA	4 x 69kV substations	ModPower	KeySpan Energy required the design and installation of four 69kV substations. It was essential for all 4 substations to be online and generating gas to the local community prior to the summer peak.
Mini-Substation for a Small-Size Geothermal Power Station, Imperial Valley, California	Mini substation with GIS SG	Siemens	The requirements specified the connection of the 50 MVA geothermal power station to the 92kV supply system via a substation equipped with a generator transformer, and able to withstand unique and extreme climate conditions.
Switchgear Extension in a Very Confined Space, Brussels, Belgium	Two bus tie units and one bus coupler unit at 170kV	Siemens	Extension of a 420/170kV substation which took up as little space as possible and with no substation shut-downs.
Kashagan Project & Karachaganak	Modular substation	Skema	No specific details but SKEMA modular substations are fully

Project, Kazakhstan, Hannibal Sour Gas Project, Tunisia			customisable.

Mobile Substations

Mobile substations tend to be installed on short term or temporary basis.

Project Information	**Equipment Supplied**	**Supplier**	**Details**
Rural Electrification in Algeria (GRTE)	3 x mobile substations which cover a wide range of 220/60-30kV ratings. Each one has 10 equipment modules, 8 of which are containerised.	ABB	Substations provided to support GRTE's electrification efforts in isolated and rural communities throughout Algeria.
Diamond Mining Site in Alrosa, Russia	Containerised HV GIS substation, 10kV SG panels, reactors, HV terminals	ABB	Requirement for a 110/10kV power supply, easily transportable solution with reduced complexity and installation time, accommodating difficult local conditions.
Copper Mining Site, KGHM Polska Miedz, Poland	110kV PASS (Plug and Switch System) & containerised MV SG including aux power unit on a standard trailer.	ABB	Temporary HV and MV power supply for a new copper mining site, easily transportable solution and not requiring any special permissions).
Fast Delivery in Anchorage, Alaska	132kV GIS substation	ABB	Substation installed in answer to Anchorage's fast growing demand for power in a discreet and compact unit for installation close to a shopping centre.
Gas Natural Fenosa, Spain	4 x 132/66kV GIS bays	Alstom	4 GIS Bays F35-132/66 kV, on a single trailer. The protection and control & auxiliary services equipment integrated as part of the trailer. No special permits for transportation.
EON, Spain	55-30/12kV 20 MVA mobile substation	Alstom	Mobile substation, including on a single platform: 55-30 kV hybrid switchgear (double ratio for choice), 20 MVA power transformer and 12 kV switchgear. General dimensions of 14.4 m x 2.5 m. MV motorised cable reels included in another trailer.
EON, Sweden	170/52.5kV 35 MVA	Alstom	Three module substation, including one special trailer for 35 MVA power transformer and two transportable containers for 170 kV and 52.5 kV GIS switchgear. The protection and control equipment needed to

			operate the bays is integrated in the containers.
REE, Spain	220kV GIS bays	Alstom	Complete 220 kV indoor GIS bay on a trailer. Protection, control & communication equipment needed to operate the bay is fully integrated. General dimensions: 13.6 m x 2.5 m. No special permits needed for transportation.
SEC, Saudi Arabia	110/13.8kV 27 MVA	Alstom	Two module mobile substation, including one trailer with 110 kV GIS switchgear and 27 MVA power transformer. A second trailer with 13.8 kV switchgear, control and protection equipment and HV and MV cable reels included.
Iberdrola, Spain	36/13.8kV 15 MVA	Alstom	Single trailer medium voltage mobile substation, including 36 kV and 13,8 kV switchgear, 15 MVA power transformer & motorised MV cable reels included. General dimensions: 11 m x 2.5 m.
PDVSA, Venezuela	115-69/13.8kV 42 MVA complete platform	Alstom	Complete substation on a single platform including 115-69 kV HYpact module, power transformer up to 42 MVA and 13.8 kV switchgear. Protection, control & communication equipment is integrated. General dimensions: 22 m x 3.8 m.
Endesa, Spain	132-66/25-10-15kV mobile substation	Alstom	Mobile substation integrating a single platform 132-66 kV GIS switchgear (double ratio for choice) and 25-10-15 kV MV switchgear (three ratios for choice). Control and protection equipment is included. General dimensions: 13.6 m x 2.5 m. No special permits needed for transportation.
UTE Cueto Soluciones, Angola	66kV GIS single bay	Alstom	Mounted in a transportable sea container, this bay includes: automatic breaker, measuring transformers, disconnectors, and the necessary equipment to properly operate and control the bay. The container is fully prepared to ensure the optimal working conditions including thermal and fireproofing of the equipment.

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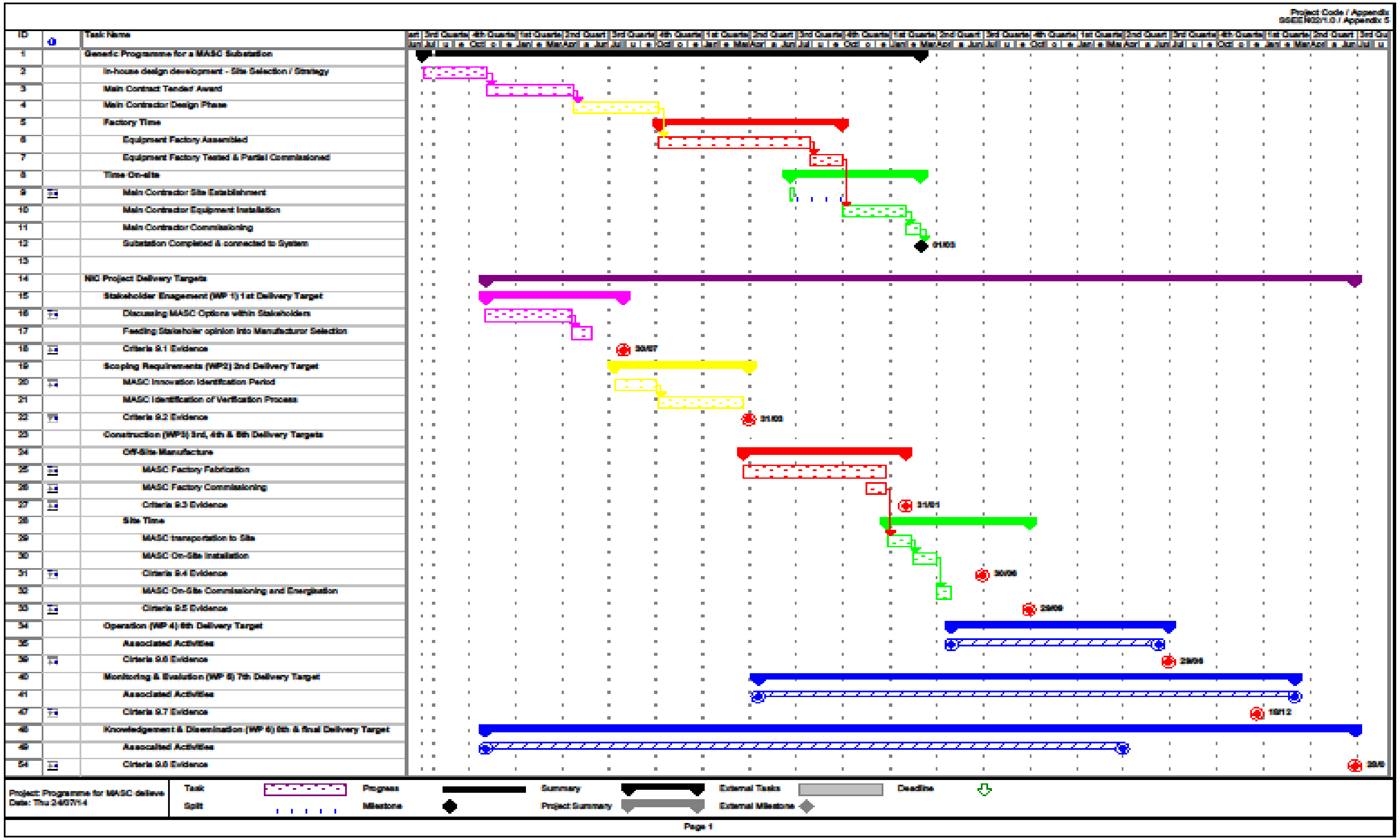
Appendix 5 Programme



Project Code/Version No:
SSEEN02/2.0

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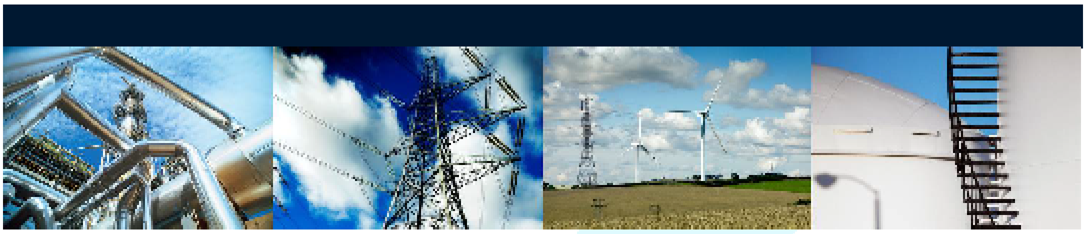

SSEEN02/1.0 - Appendix 6a –

Modular Approach to Substation Construction – Market Assessment

To:	Frank Clifton	Company:	TNEI
From:	Anna Ferguson	Project Reference:	9328- MASC 02-R1- NIC -Bid
Date:	25 July 2014		

1. Generation Substations

Objective

The objective for the market assessment was to understand how many projects could be suitable for deploying modular substations up to 2030. It has been assumed that the new substations could be deployed to connect new generation projects to the networks at 132kV, and that three sizes of modular substation could be defined:

- 30 – 60MW
- 60 – 90MW
- 90 – 150MW

Methodology

To understand potential projects in the SHE Transmission and Scottish Power Transmission areas, National Grid's Transmission Entry Capacity (TEC) register was used. This register identifies projects in various stages of development and covers the next seven years of development approximately. The project status is described in the TEC register as "Scoping", "Awaiting Consents", "Consents Approved", "Under Construction/ Commissioning" and "Built". In order to assess the potential projects in these areas, the following analysis was carried out:

- The projects were grouped by Transmission Owner (TO), i.e. SHE Transmission, SPT and NGET;
- The project size was grouped into bands as follows: <30MW, 30-60MW, 60-90MW, 90-150MW and >150MW;
- The projects were then grouped by project status.

In order to understand the number of potential projects that could be suitable for modular substation deployment from this list, "Built" projects were not included.

Projects below 30MW were not included, as although some of these could potentially be connected at 132kV, it was not possible from the TEC register to determine whether these would be connected at transmission or distribution level. In addition, projects greater than 150MW were excluded as it is more likely that these would connect at 275kV or 400kV.

As 132kV is a transmission voltage in Scotland but a distribution voltage in England and Wales, the 132kV projects in England and Wales are not listed in the TEC register. Therefore the Distribution Network Operators' (DNOs') Long Term Development Statements (LTDS) were examined in order to find potential 132kV projects in England and Wales. For each DNO, the projects that had offers accepted, but were not connected, were identified. As for the TEC register, these projects were categorised by their generation band. Additional projects were identified in the following DNO areas:

- WPD West Midlands, WPD South West, WPD South Wales and WPD East Midlands;
- NPG North East and Yorkshire.

For UKPN and ENW, 132kV connected projects were identified, but there were none that had both (i) offers accepted and (ii) were not connected.

Unlike the TEC register, in the LTDS information the connection voltage is given, and therefore projects accepted to connect at 132kV were included.

National Grid's Future Energy Scenarios (FES) analysis was used to understand the projects that might be developed up to 2035, and this was extended to provide a 2050 analysis. The total predicted onshore renewables capacity between 2014 and 2020 was found for the "Slow Progression" and the "Gone Green" scenarios, and this was compared with the total project capacity from the TEC register and the LTDS. According to the comparison, approximately 30% of the projects in the TEC and LTDS would go ahead in the "Slow Progression" scenario and approximately 65% of the projects would go ahead in the "Gone Green" scenario.

The average number of projects per annum that would be suitable for implementation of a modular substation was therefore calculated, and from 2020 onwards this number was grown based on the annual percentage growth in onshore renewables from the FES analysis up to 2035. From 2035 to 2050, an average growth rate was applied for each scenario based on the average growth rate for the last year of FES.

Results

The combined results from the TEC register and LTDS for England and Wales, SHE Transmission and SPT areas are given in Figure 1 and Figure 2 below. This shows the three bands of generation project identified above; the projects given all have a status of "Scoping", "Awaiting Consents", "and Consents Approved "or" Under Construction / Commissioning". Figure 1 identifies the projects by generation size, and Figure 2 identifies the projects by project status.

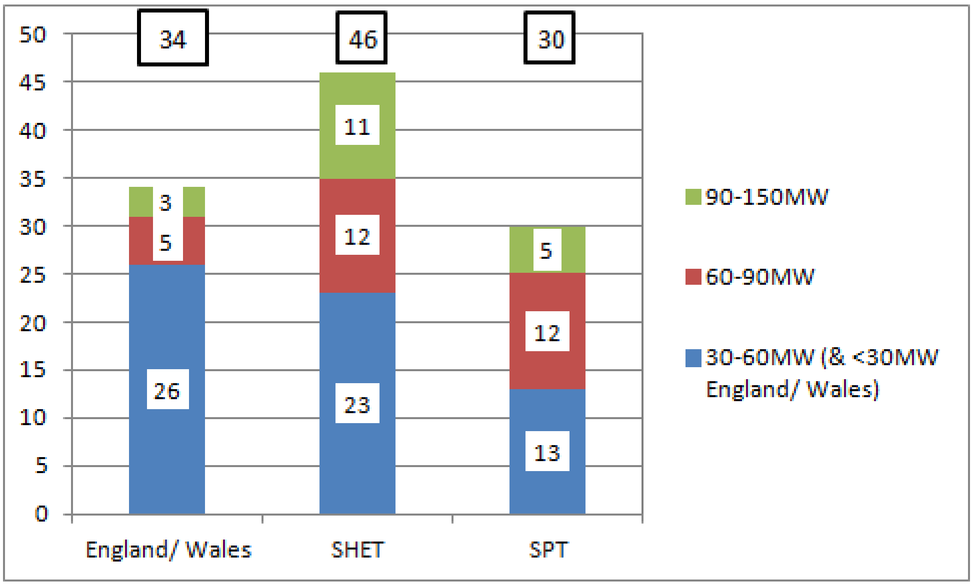

Figure 1 – Total number of 132kV projects in England/ Wales and Scotland grouped by Project Size for 2014-2020

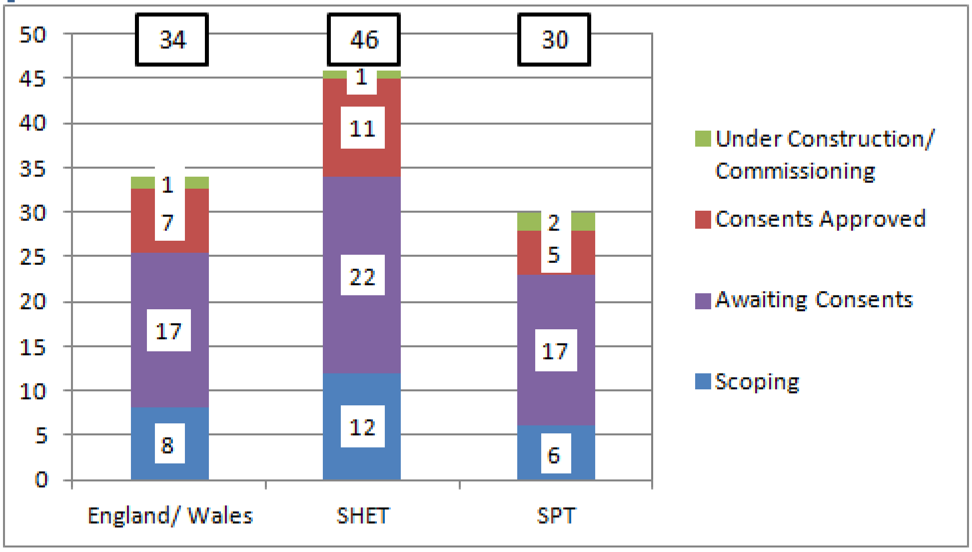

Figure 2 – Number of 132kV projects in England/ Wales and Scotland grouped by project status

Using the methodology described above, the average number of projects per annum for 2014, 2020, 2030 and 2050 are presented in Table 1 and the cumulative number of projects per annum for 2014, 2020, 2030 and 2050 are presented in Table 2.

To illustrate the application of the methodology, the following calculations give examples to show how the numbers were obtained for 2014:

$$\textit{Slow Progression (England \& Wales)}: {}^{34}/_{7} \times 0.3 = 1.5 \textit{ projects per annum}$$

$$\textit{Gone Green (SHET)}: {}^{46}/_{7} \times 0.65 = 4.3 \textit{ projects per annum}$$

Table 1 – Average Number of Projects per Annum

# Projects/ Annum	**Year**	**2014**	**2020**	**2030**	**2050**
Slow Progression					
NGET		1.5	1.5	2.5	3.0
SHET		2.0	2.0	3.3	4.0
SPT		1.3	1.3	2.2	2.6
Total		**4.7**	**4.7**	**8.0**	**9.6**
Gone Green					
NGET		3.2	3.2	5.3	6.4
SHET		4.3	4.3	7.2	8.7
SPT		2.8	2.8	4.7	5.7

Total		**10.2**	**10.2**	**17.2**	**20.7**

Table 2 – Cumulative Number of Projects

# Projects/ Annum	**Year**	**2014**	**2020**	**2030**	**2050**
Slow Progression					
NGET		1.5	10.2	31.0	85.6
SHET		2.0	13.8	42.0	115.8
SPT		1.3	9.0	27.4	75.5
Total		**4.7**	**33.0**	**100.4**	**277.0**
Gone Green					
NGET		3.2	22.1	67.2	185.5
SHET		4.3	29.9	91.0	251.0
SPT		2.8	19.5	59.3	163.7
Total		**10.2**	**71.5**	**217.5**	**600.1**

In the same way, the average and cumulative capacity in MW per annum has been calculated. This is given in Table 3 and Table 4. The average project capacity has been calculated to be 58MW.

Table 3 – Average Capacity per Annum (MW)

# Projects/ Annum	**Year**	**2014**	**2020**	**2030**	**2050**
Slow Progression					
NGET		71.1	71.1	120.0	144.4
SHET		116.6	116.6	196.7	236.7
SPT		86.4	86.4	145.8	175.4
Total		**274.2**	**274.2**	**462.5**	**556.6**
Gone Green					
NGET		154.2	154.2	260.1	313.0
SHET		252.6	252.6	426.2	512.9
SPT		187.2	187.2	315.8	380.1
Total		**594.0**	**594.0**	**1002.1**	**1206.0**

Table 4 – Cumulative Capacity (MW)

# Projects/	**Year**	**2014**	**2020**	**2030**	**2050**

Annum					
Slow Progression					
NGET		71.1	498.0	1515.1	4180.2
SHET		116.6	816.2	2483.2	6851.1
SPT		86.4	604.9	1840.1	5076.9
Total		**274.2**	**1919.1**	**5838.5**	**16108.2**
Gone Green					
NGET		154.2	1079.1	3282.8	9057.1
SHET		252.6	1768.5	5380.3	14844.1
SPT		187.2	1310.5	3987.0	10999.9
Total		**594.0**	**4158.1**	**12650.1**	**34901.1**

Conclusion

From the results shown above, it is predicted that a total of 33, 100 and 277 projects will have been built by 2020, 2030 and 2050 respectively assuming National Grid's "Slow Progression" scenario. For the "Gone Green" scenario, it is predicted that a total of 72, 218 and 600 projects will have been built by 2020, 2030 and 2050 respectively.

2. Transmission Reinforcement Substations

Objective

In addition to the use of modular substations for connecting new generation at 132kV, there is the potential for these substations to be used in transmission upgrades in the future. The potential benefit for these substations used in new reinforcements has therefore been estimated.

Methodology

The proposed and planned reinforcements for Scotland, England and Wales have been determined from publically available information. From this information, the number of new HVAC substations has also been determined. Ofgem has stated that approximately £7bn of investment is being made available for Scotland transmission upgrades and approximately £15.5bn for England and Wales transmission upgrades in the RIIO-T1 price control period. From these figures, the number of new HVAC substations required for England and Wales has been estimated.

Results

The Scottish upgrades (SPT and SHE-T) are given in the table below:

Table 5 – Reinforcements in Scotland: 2013-2020

TO	Reinforcement	Works Description	Reinforcement Technology	Number of New HVAC Substations	Status	Expected Completion Date
SHE-T and SPT	Beauly-Denny Overhead Line (OHL) Reinforcement	Replace existing 132kV OHL with new 400kV tower construction.	Replace existing HVAC OHL	6 (Beauly, Fasnakyle, Fort Augustus, Tummel Bridge, Braco, Denny)	Under Construction	2015
SHE-T	Foyers-Knocknagael	Replace conductors on existing 275kV OHL	Reconductor HVAC	1 (Knocknagael)	Development	2015
SHE-T	Beauly-Blackhillock-Kintore 275kV	Replace conductors on the existing 275kV double circuit line with higher capacity conductors.	Reconductor HVAC	None	Under Construction	2015
SHE-T	Beauly-Dounreay	Installation of second 275kV circuit on existing towers	Additional HVAC circuit	2 (adjacent to Dounreay substation)	Complete	Spring 2013
SHE-T	East Coast 400kV	Re-insulate the existing 275kV circuit between Blackhillock and Kintore and Kincardine for 400kV operation. New 400kV busbars and new Phase Shifting transformers.	Re-insulate OHL, new busbars and new transformers.	3 (Kintore, Rothienorman, Haughend)	Consenting	2016-2019
SHE-T	Western Isles HVDC	New 450MW HVDC link from a new substation at Gravir on Lewis to Beauly 400kV.	New 450MW HVDC link	1 (Stornoway)	Development	2018+
SHE-T	Caithness-Moray-Shetland (CMS)	New HVDC converter at Spittal in Caithness. New 1200MW HVDC subsea cable to new 1200MW converter at Blackhillock in Moray. New 600MW HVDC link from Shetland to integrate with Caithness-Moray.	3-terminal HVDC link	7 (Blackhillock, Spittal, Fyrish, Loch Buide, Dounreay, Mybster, Kergord)	Scoping	2018
SHE-T	Kintyre-Hunterson Link	Two new 220kV subsea cables between new substation at Crossaig and Kintyre and Hunterston in Ayrshire. Installation of phase shifting transformers at Crossaig.	New HVAC cables, new PSTs, re-conductor HVAC	1 (Crossaig)	Development	End 2015
SHE-T	Orkney HVAC	New AC subsea cable from new substation near the Bay of Skaill on Orkney to Dounreay.	New HVAC	1 (Orkney)	Development	2018
SHE-T	Orkney HVDC	New 600MW HVDC link to Caithness to integrate with the Caithness-Moray Reinforcement.	VSC-HVDC	None	Scoping	2020?
SHE-T and SPT	East Coast HVDC link	New 2GW submarine HVDC cable route from Peterhead to North East of England.	New HVDC cable	1 (Peterhead)	Development	2019/2020

TO	Reinforcement	Works Description	Reinforcement Technology	Number of New HVAC Substations	Status	Expected Completion Date
SHE-T	Inverarnan Substation	New 275/132kV substation at Inverarnan	HVAC substation	1 (Inverarnan)	Complete	2010
SHE-T	Beauly-Mossford	New HVAC overhead lines and substation	HVAC	1 (Corriemoillie)	Construction	2015
SPT	South West Scotland	New 132kV overhead line and substations	HVAC OHL and substation	8 new SPT substations	Construction/ Consenting	2017
SPT	Shunt compensation	Install shunt capacitors at Windyhill, Longannet, Elvanfoot and Moffat	Shunt capacitors (FACTS)	None	Construction	2013
SPT	Series compensation and OHL upgrades	Series capacitors, upgrade of OHL from 275kV to 400kV and new 400kV OHL circuits	FACTS and HVAC upgrades	None	Construction	2015-2018
SPT	Western HVDC Link	400kV HVDC link from Hunterston in Ayrshire to Deeside in Wales.	CSC-HVDC	None	Scoping	2015-2016
SPT	Dumfries & Galloway Upgrade	New 275kV OHL from Harker to Auchencosh	New HVAC OHL	9 (estimated from schematic)	Scoping	TBC
SHE-T	**Substations**			**23**		
SPT	**Substations**			**19**		
Total				**42**		

Therefore, approximately 42 new substations will be required for the Scotland upgrades. From the RIIO T1 investment figures, it can be inferred that approximately 93 new substations will be required in this period for England and Wales (15.5/7 × 42 = 93). Therefore, a total of approximately 135 substations will be required for Scotland, England and Wales in the RIIO-T1 period.

These projects have been extrapolated for Slow Progression and Gone Green scenarios in the same way as per the generation substation projects. The results are shown below:

Table 6 – Average Number of Reinforcement Substations per Annum

# Projects/ Annum	**Year**	**2014**	**2020**	**2030**	**2050**
Slow Progression					
NGET		4.0	4.0	6.7	8.1
SHET		1.0	1.0	1.7	2.0
SPT		0.8	0.8	1.4	1.7
Total		**5.8**	**5.8**	**9.8**	**11.7**
Gone Green					

NGET		8.6	8.6	14.6	17.5
SHET		2.1	2.1	3.6	4.3
SPT		1.8	1.8	3.0	3.6
Total		**12.5**	**12.5**	**21.1**	**25.5**

Table 7 – Cumulative Number of Reinforcement Substations

# Projects/ Annum	**Year**	**2014**	**2020**	**2030**	**2050**
Slow Progression					
NGET		4.0	27.9	84.9	234.2
SHET		1.0	6.9	21.0	57.9
SPT		0.8	5.7	17.3	47.8
Total		**5.8**	**40.5**	**123.2**	**339.9**
Gone Green					
NGET		8.6	60.5	183.9	507.4
SHET		2.1	15.0	45.5	125.5
SPT		1.8	12.4	37.6	103.7
Total		**12.5**	**87.8**	**267.0**	**736.5**

Table 8 Projects and Reinforcements

# Projects/ Annum	**Year**	**2014**	**2020**	**2030**	**2050**
Slow Progression					
NGET		5.5	38.1	115.9	319.8
SHET		3	20.7	63	173.7
SPT		2.1	14.7	44.7	123.3
Total		**10.6**	**73.5**	**223.6**	**616.8**
Gone Green					
NGET		11.8	82.6	251.1	692.9
SHET		6.4	44.9	136.5	376.5
SPT		4.6	31.9	96.9	267.4
Total		**22.8**	**159.4**	**484.5**	**1336.8**
	50%	**11**	**80**	**242**	**668**

Conclusion

From the results shown above, it is predicted that a total of 41, 123 and 340 HVAC transmission reinforcement substations will have been built by 2020, 2030 and 2050 respectively assuming National Grid's "Slow Progression" scenario in order to upgrade the transmission networks in Scotland, England and Wales. For the "Gone Green" scenario, it is predicted that a total of 88, 267 and 737 HVAC substations will have been built by 2020, 2030 and 2050 respectively. Table 8 shows the total number of possible sites where the method could be used this is made up of the total generation sites from Table 2 and the total transmission reinforcement sites from Table 7. It is these figures that are used for the project benefits tables.

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Appendix 7a – Business Case Additional

Purpose

This appendix provides further supporting information on the project's Business Case.

Substation Component Costs

The design and construction of a typical air-insulated substation is described in detail in Appendix 2. To quantify the benefits of MASC, it is useful to explore elements involved with construction and operation of a substation, as described in Figure 1, below.

Substation construction and operation elements	
Civil cost	This includes the clearance, excavation and preparation of the site to ensure that it is suitable for the equipment. For conventional substations this will also include the construction of foundations, structures and supports for the electrical equipment.
Building cost	Buildings are generally provided to store protection and control systems including switchgear. In more remote or coastal environments, all equipment is generally located indoors.
Transformer	The cost of a transformer is a significant element of the overall cost of a substation.
HV switchgear and associated equipment	This includes circuit breakers, disconnectors, earth switches, voltage transformers, current transformers etc for the high voltage side of the substation typically 132,275 or 400kV. This includes the protection and control equipment
LV - 33KV equipment	This includes circuit breakers, disconnectors, earth switches, voltage transformers, and current transformers for the low voltage side of the substation (typically 11kV, 33kV or 132kV).
Miscellaneous	Other elements include metering, telecoms, SCADA/RTS, battery charger, low voltage AC and other ancillaries. The cost of consents and environmental surveys is also included.
Project Management	This includes engineering time and site establishment.
Land Cost	Cost of the land for the substation.
Off- site infrastructure	Cost of establishing new access roads, strengthening existing roads.

Figure 1 Key elements involved in the construction and operation of a substation

The elements described in Figure 1 have been used as a basis upon which to establish the typical cost of a substation; the cost breakdown is as shown in Figures 2 and 3 for an AIS and GIS substation. For the purposes of this exercise the land cost and cost of the off site infrastructure have been excluded.

The costs described below are based around a typical 132/33kV 60-90MVA substation. The cost information has been collated from information contained in the TOs' Charging Statements and compared with typical SHE Transmission historic cost data. From this analysis, SHE Transmission has identified that the total cost of a 60-90 MVA substation is typically between £3.5m and £6.5m. For the purposes of this analysis it has been assumed that an average cost will be around £4.9m per substation.

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Figure 2 Chart depicting the percentage and types of costs attributed to a traditional, air-insulated substation

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Figure 3 Chart depicting the percentage and types of costs attributed to a traditional,

Redaction (graph removed)

Figure 4 Chart depicting the percentage of costs attributed to elements of substation construction projects

The final cost of each installation will vary according to location, site details, electrical network, transformer rating and the number of incoming and outgoing feeders.

However, from this exercise it was estimated that the typical cost of a new build substation is approximately £4.9m.

Substation Costs – MASC Approach

As stated within the main document the MASC approach and the move to off-site construction will reduce the cost of substation construction in a number of areas, including:

- **Standard Components**: Current design practises for new substation construction and operation generally result in a near "bespoke" design based around the use of a standard set of component. Equipment suppliers are increasingly offering innovative modular substation components which have been proven in other sectors.
- **Increased flexibility**: Traditional substations are very "fixed" in nature; there are only limited options for increasing or decreasing capacity without significant works.
- **Transport and access costs**: The modular equipment being proposed is designed to be transported and installed easily on site; therefore, reducing the requirement for civil works etc. This should reduce the overall cost of construction.
- **Footprint and civil works**: The use of a more modular design will facilitate a reduced overall footprint and less complex civil requirements.
- **Off-site manufacture**: The use of a modular approach will maximise the use of off-site manufacture and commissioning. This should significantly reduce the time required to install and commission the equipment on site, this is particularly beneficial for projects located in remote areas.
- **Reduced construction duration**: As identified above a modular approach will look to optimise the use of off site manufacture and commissioning, this combined with the reduced civil works requirement will result in shorter time being required on site.

Based on early engagement with the supply chain and internal stakeholders it has been possible to estimate the cost of a similar project using MASC, as shown in Figures 4 and 5, below.

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Figure 4 Chart depicting the percentage and types of costs attributed to a MASC substation

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Figure 5 Cost break-down for modular substation components

From this early analysis it can be seen that the move to a modular approach has the potential to reduce costs by up to 20% compared to the traditional alternatives. Figure 6 below indicates the comparison between AIS, GIS and MASC

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As can be seen from Figure 6 above there is an increase in the cost of the electrical equipment in the MASC solution which is off set by a reduction in the cost of civil works, building works, project management etc. These benefits which arise due to a focus on off site assembly and commissioning should be directly applicable to a wide range of both infrastructure and connections projects.

As indicated above the move to a modular approach reduces costs and delivers benefits for customers. If this is combined with the information contained in the Market Assessment document, prepared by TNEI in Appendix 6a, then the overall benefits from MASC can be estimated. The Total Benefits from the project are summarised in Figure 8, below.

No of projects by 2050	Slow Progression	Gone Green
Total number of potential substations	617	1337
Total Connection Projects	277	600
Total Infrastructure projects	339	736
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

Figure 7 Table depicting the financial benefits from MASC

As identified previously, all of the benefits which arise from cost reductions in infrastructure projects will flow directly to transmission customers. The benefits which will arise from reduction in the cost of connection projects will be shared between transmission customers and connection customers (primarily renewable developers).

The actual cost split is governed by the requirements of the CUSC, but typically the infrastructure element of the connection project, which is recovered from transmission customers, comprises up to 25% of the project total. The remaining sole user costs are borne by the connection applicant. The move to a modular solution will be applicable to both the sole use and infrastructure elements of the project, therefore, both should benefit from reductions of up to 20%.

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SSEEN02/2.0

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SSEEN02/1.0 MASC Appendix 7b Financial and Carbon Benefits

Method	Method name
Method 1	The MASC project only proposes a single method ie the demonstration and deployment of a Modular Substation. To help with understanding a number of scenarios for the uptake of the MASC solution have been identified. These are presented below.
Method 2	[Insert method names here]
Method 3	[Insert method names here]

Financial benefit (£m)

Scale	Method	Method Cost	Base Case Cost	Benefit 2020	Benefit 2030	Benefit 2050	Notes	Cross-references
Post-trial solution (individual deployment)	Method 1						[redacted]	[redacted]
	Method 2							
	Method 3							
Licensee scale If applicable, indicate the number of relevant sites on the Licensees' network.	Scenario 1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Scenario 2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
	Scenario 3	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
GB rollout scale If applicable, indicate the number of relevant sites on the GB network.	Scenario 1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Scenario 2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
	Scenario 3	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		

<table>
<tr><th colspan="9">Capacity released and/ or environmental benefit (kVA/ kWh)</th></tr>
<tr><th>Scale</th><th>Method</th><th>Method Cost</th><th>Base Case Cost</th><th>2020</th><th>2030</th><th>2050</th><th>Notes</th><th>Cross-references</th></tr>
<tr><td rowspan="3">Post-trial solution (individual deployment)</td><td>Method 1</td><td></td><td></td><td></td><td></td><td></td><td rowspan="3">[explain circumstances where benefits may be larger or less that those stated – including the upper and lower limits]</td><td rowspan="3">See Appendix 6a for further details</td></tr>
<tr><td>Method 2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Method 3</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Licensee scale If applicable, indicate the number of relevant sites on the Licensees' network.</td><td>Method 1</td><td></td><td></td><td></td><td></td><td></td><td rowspan="3">(Number of sites:___)</td><td rowspan="3">See Appendix 6a for further details</td></tr>
<tr><td>Method 2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Method 3</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">GB rollout scale If applicable, indicate the number of relevant sites on the GB network.</td><td>Method 1</td><td></td><td></td><td></td><td></td><td></td><td rowspan="3">(Number of sites:___)</td><td rowspan="3">See Appendix 6a for further details</td></tr>
<tr><td>Method 2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Method 3</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>If applicable, indicate any carbon and/or environmental benefits which cannot be expressed as kVA or</td><td colspan="6">Post-trial solution: [Explain any carbon and/ or environmental benefits which cannot be expressed as kVA or kWh]</td><td>There are a number of key environmental benefits which will arise from MASC, these predominantly arise from the reduction in civil works, vehicle movements etc which occur with the move to an Off Site based approach</td><td>See Appendix 6a for further details</td></tr>
</table>

kWh.	**Licensee scale:** [Explain any carbon and/ or environmental benefits which cannot be expressed as capacity or kVA or kWh]	to construction and commissioning. The savings will be very much dependent on the specific details of the site. The cost reductions which will arise from a wide spread adoption of the MASC approach will help to reduce the cost of connection to the network for renewable developers. This will help ensure that more planned renewable develops are financially viable and therefore proceed to completion. This will help the UK achieve it renewable and carbon reduction targets.	
	GB rollout scale: [Explain any carbon and/ or environmental benefits which cannot be expressed as kVA or kWh]		

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Appendix 8 – Risk Register & Contingency Plan

The Risk Management Process for the MASC is designed to address all of the relevant activities described in the 'risk house of control' shown. It is aligned with SSE's Business Risk and Internal Control Policy Framework.

This process will help to ensure that the required standards and considerations of both risks, and opportunities, are being followed. Additionally, the Risk Management Process allows for all the project level risks to be consolidated and therefore regularly and systematically reported, considered, and managed at a group level.

Risk Review Workshops shall be held during the project, which are used to identify new Risk and plan their mitigations. .

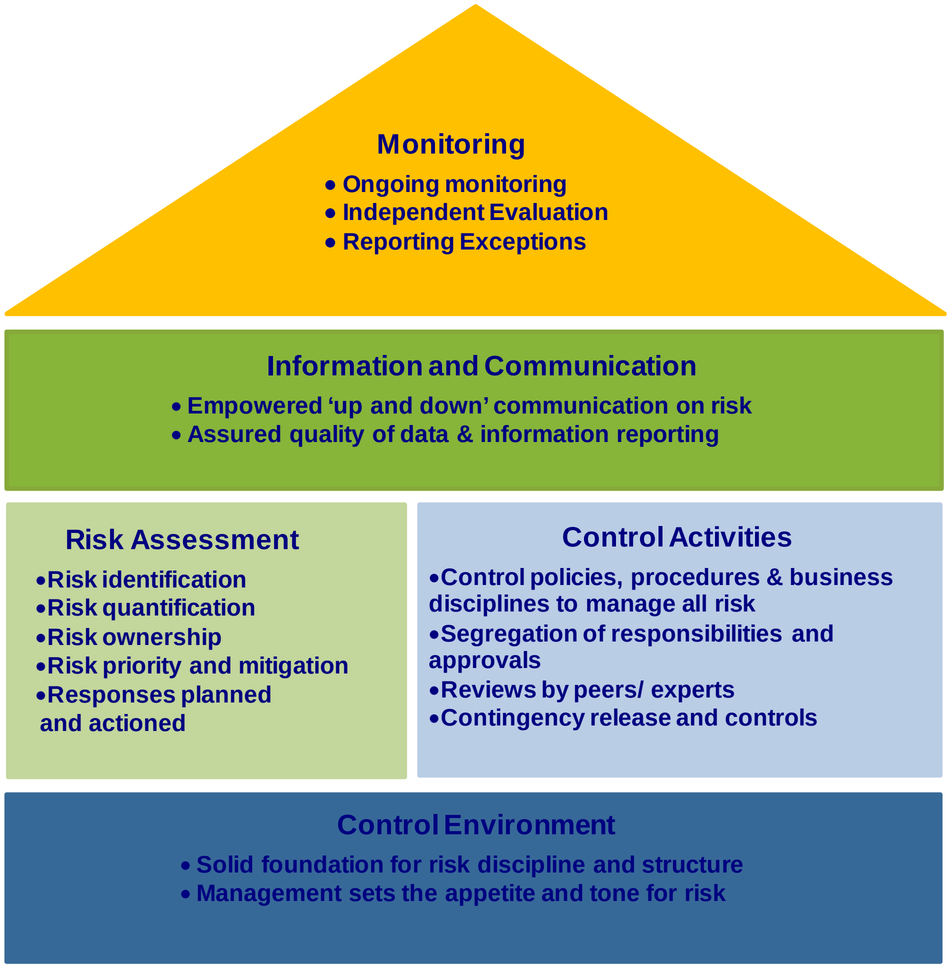

Figure 1: Risk House of Control

The following table shows an extract from the project's risk register.

Ref	Category	Title	Description	Severity or Impact				Likelihood	Risk Factor	Impact of Risk	Mitigation actions
				P	R	O	F				
R001	External Engagement	Site Identification	Need to identify suitable site for first MASC application.	0	2	2	3	**2**	**7**	Delays the selection of MASC trial site, delaying the realisation of benefits	Identify appropriate projects and engage with developer early. This will allow early development of designs, considered risks and well thought through mitigation strategies
R002	External Engagement	System Operator Acceptance	NG as System Operator have leverage on the end solution	0	2	2	3	**2**	**7**	Delays in the deployment of the MASC trial, to resolve NG issues, knock-on effect though to the Developer	Early engagement with NG to identify and resolve identified and perceived challenges
R003	Programme	Delay in Connection of MASC	Through site selection challenges or slippage in Developers generation commissioning	0	3	0	2	**3**	**5**	Delay in connection of the MASC Trial	Well developed designs and structured engagement with the Developer. Slippage on the Developers commissioning dates is unpreventable, open communication channels will aid in managing timings
R004	Technical	MASC - European Equipment	Short deployment Timescales could mean reliance on European standard Equipment.	1	0	2	3	**2**	**6**	Different to standard UK equipment; non-compliant with UK operational safety requirements	Early identification and engagement with manufacture to identify equipment that challenges UK operational safety rules, therefore enabling solutions ensure the operation of the

Ref	Category	Title	Description	Severity or Impact				Likelihood	Risk Factor	Impact of Risk	Mitigation actions
				P	R	O	F				
											MASC system
R005	Technical	MASC Maintenance	The MASC design may require the complete circuit to be turned off before the door can be opened	1	2	1	1	**3**	**5**	If the whole circuit to be switched the generator will be unable to access the system	Discussion with Developers who have selected a non-firm connection. Understand the maintenance requirements, ensure programming of necessary works is during periods of naturally low generation output
R006	Technical	MASC Innovation	The MASC design not as dynamic or suitable to fit.	0	3	0	2	**2**	**5**	Defeats the envisaged modular approach / benefits. Technology not as advanced yet.	Early engagement with supply chain to understand equipment availability. Use generic requirements specification from NIA project to develop requirements.
R007	Technical	MASC Protection & Control	Off site commissioning or Plug and Play' wiring solutions not satisfactory	1	1	2	2	**2**	**6**	Commissioning and Operations refuse to adopt new technology.	Early engagement and identification of concerns from the commissioning and Operations Teams. Use Functional spec to ensure that their needs are satisfied.
R008	Project Management	Control & maximising learning	Engaging with key people, interfacing with the manufacture and identifying the opportunities	1	1	0	1	**3**	**3**	Not having people 'onboard', difficulty sourcing the right internal support, therefore learning not identified.	Early engagement, early consideration of resources, openness with other business areas to generate interest.
R009	Learning and Dissemination	Future Usage Options	Future usage options (learning objective iii) developed during project become obsolete due to changes in legislation or forecast network	0	2	0	0	**2**	**2**	Project impact and route to BAU is not clearly defined or understood	Future usage options will be developed for a range of possible scenarios and levels of renewable/EV uptake.

Ref	Category	Title	Description	Severity or Impact				Likelihood	Risk Factor	Impact of Risk	Mitigation actions
				P	R	O	F				
			architecture								
R010	Learning and Dissemination	Poor attendance	Poor attendance / engagement at dissemination events	1	3	0	0	**2**	**4**	Project outcomes not widely understood and not adopted into BAU	Events advertised to specific audiences, accessible by internet, and content tailored to feedback.
R011	Learning and Dissemination	Decision tool not useful	Decision tool is too high-level, or too complex to be useful	1	2	0	0	**1**	**3**	MASC less likely to be considered as an option in early projects.	Tool will balance ease-of-use with level of detail to encourage projects to consider MASC as an option early in project
R012	Learning and Dissemination	Loss of key knowledge	Key knowledge and lessons learned are not recorded due to staff leaving or changing roles.	1	2	0	0	**2**	**3**	Lessons from early in project more likely to be lost through personnel changes	Exit interviews to include lesson capture with all departing project members; a lessons learned log will be available throughout project and staff encouraged to populate as learning arise.
R013	Learning and Dissemination	Poor uptake of MASC outputs	Low engagement with/use of project outputs	0	2	0	0	**2**	**2**	Project outcomes are shelved and technology less likely to become widely adopted	Decision tool and simulator make continued engagement after project end more likely. Take-up of project outputs will be monitored and additional dissemination events or training scheduled if necessary.

Table 3 MASC project risk log

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Mitigation and Contingency Plan

The following Table shows the mitigation measures which we would adopt for the thirteen risks in described in the Risk Register which have a risk factor of 6 or above.

Ref	Risk	Immediate Actions	Interim Measures	Long Term Recovery
R001	External Engagement - Need to identify suitable site for first MASC application	Identify appropriate projects which have achieved planning consent and engage with developer early to agree use of MASC solution.	Identify sites awaiting planning consent and include MASC solution along with application	Identify other sites where MASC may be applicable.
R002	External Engagement - NG as System Operator have leverage on the end solution	Early Engagement with SO to ensure that the solution is acceptable. Identify areas where existing policy and codes etc need to be changed.	Work with supply chain to ensure that standard equipment is modified to fully meet requirements of GB market.	
R004	Technical - Short deployment Timescales could mean reliance on European standard Equipment	Early identification and engagement with manufacturers to identify equipment that challenges UK operational safety rules, therefore enabling solutions ensure the operation of the MASC system	Work with supply chain to ensure that standard equipment is modified to fully meet requirements of GB market.	
R007	Technical - Off site commissioning or Plug and Play' wiring solutions not satisfactory	Early engagement and identification of concerns from the commissioning and Operations Teams. Use Functional spec to ensure that their needs are satisfied	Work with supply chain to ensure that standard equipment is modified to fully meet requirements.	Develop new operational processes etc to allow deployment of new technology.

RIIO NIC NETWORK INNOVATION COMPETITION

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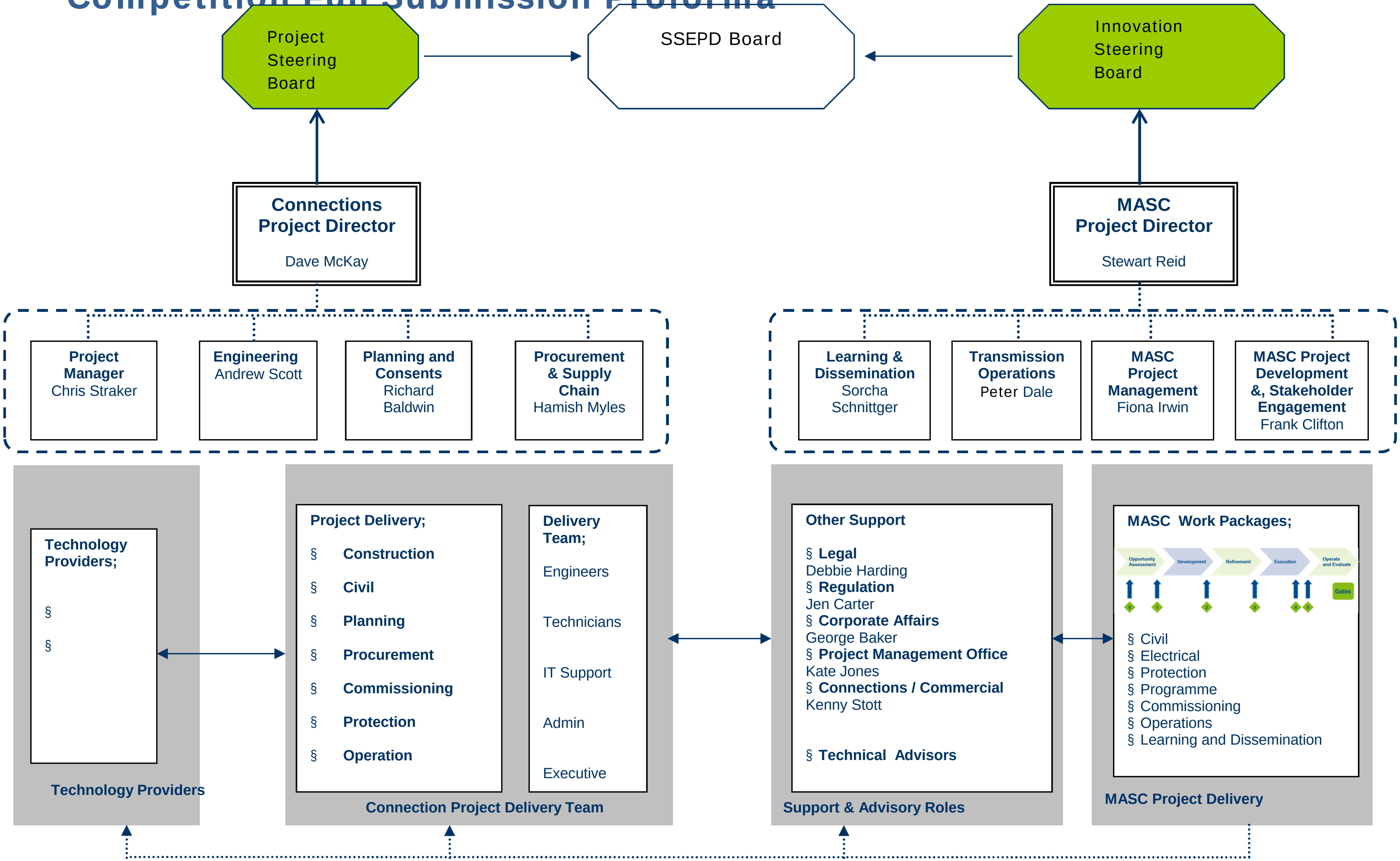

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Appendix 10 – Funding Commentary

Purpose

This appendix describes the assumptions made in developing the project costs.

Overall Cost Assumptions

All internal resource costs are based on a rate of [redacted] per day, which includes an allocation of all overheads.

- All external resource costs are based on an average rate of [redacted] per day (based on the assumption that this is expert professional resource).

Travel and Expenses estimated at [redacted] of external resource cost, and [redacted] of internal resource costs.

Refer to the Resource Plan in Appendix 14 for the assumed internal and external resource requirements for the project.

All estimated costs have been inflated by the annual inflation rates provided by Ofgem.

Work Package 1 (Project Management) Cost Assumptions

The Work Package 1 costs cover Years 1 to 5 and are based on:

Key personal required to drive and deliver the successful MASC Project. Estimated at [redacted].

Project Management Support to support the delivery of the MASC project – assumed as [redacted].

IT specific support and integration into SSE systems. Estimated at [redacted]

Additional costs associated with supporting stakeholder engagement activities, to gain their input to the MASC project. Estimated at [redacted]

Work Package 2 (Scoping Requirements) Cost Assumptions

Work Package 2 is phased over the first two years; it centres round evaluation, research and future applications, with the costs based upon;

Civil and structural investigation, estimated at [redacted]

Evaluation of MASC on present SSE Safety Working policies and asset transportation proposals, estimated at [redacted]

Investigate the operational impact of MASC, along with the necessary level of system integration, estimated at [redacted]

Evaluation of the different elements of MASC, identify potential opportunities elsewhere within SHE Transmission were their application could be replicated if suitable, estimated at [redacted]

Work Package 3 (Construction) Cost Assumptions

Work Package 3 occurs between years 2 – 4, as MASC enters the fabrication phase and as includes all the associated aspects to allow onsite installation, the costs are based on:

- Revision / amendment of original planning consents based upon the MASC proposal and capturing learning to develop strategies for subsequent MASC schemes, estimated at [redacted].
- Associated equipment cost for the first time UK deployment to be permanently installed in the UK, including measures adopted to ensure standard reliability and external system verification. Estimated at [redacted].
- Additional commissioning validation, inclusive of more onerous monitoring equipment and testing. This includes staff attending factory based commissioning and testing of MASC equipment. Travel and substances expenses are also included within the estimate of [redacted].
- Additional cost of for operational personnel to learn and gain knowledge through exposure to the MASC innovation at the fabrication and site installation phase, estimated at [redacted].
- Preparation of new training, operational, and safety procedure and process documentation, along with provision for seeking any necessary amendments to existing operating codes is estimated at [redacted].

Work Package 4 (Operation) Cost Assumptions

Work Package 4 occurs between years 3 – 5, as MASC enters the operational phase the costs are based on:

- Evaluation and alignment of functional and technical specifications for the MASC, estimated at [redacted].
- Assessment of the civil and structural MASC elements under operation, estimated at [redacted].
- Development and implementation of Safe Working procedures estimated at [redacted].
- Deploying MASC operationally into the SHE Transmission “business as usual” practise, estimated at [redacted].

Work Package 5 (Monitor and Evaluate) Cost Assumptions

Work Package 5 occurs between years 3 -5 this may be earlier then expected but necessary to monitoring the electrical equipment during transportation will be essential for instance. The costs are based on;

- Monitoring and data download including vibrations, volumes, noise, thermal imaging, CCTV and electrical discharge, but not limited too the aforementioned. Estimated at [redacted].

Evaluation of the data leading to conclusions and recommendations, which may also highlight modifications or additional investigations. Estimated at [redacted].

Evaluation of the end MASC solution, reconciling envisaged application to other SHE Transmission Business areas, estimated at [redacted].

Additional sum for monitoring and evaluation, which could include University research through to computer programmes to manage and analyse data, estimated at [redacted].

Work Package 6 (Knowledge & Dissemination) Cost Assumptions

Work Package 6 occurs throughout the project period to maximise the learning opportunities the costs are based on;

Development of IT knowledge management application to benefit MASC, estimated at [redacted].

Showcasing the MASC project at Industry Events, including travel and substance, estimated at [redacted].

Facilitating Lesson Learnt Workshops and development of a decision tools to enable site selection, estimated at [redacted].

Reporting on knowledge and dissemination of learning associated with MASC, including SSE Communication management, estimated at [redacted].

Development of a virtual simulation tool and associated training materials and IT equipment estimated at [redacted].

Achieving Best Value -

The following table summarises the measures to be taken to ensure that the project is managed within the identified budget.

Table 1 - Major Cost Items – Risks / Mitigation

Major Cost Item	Ensuring Value for Money
Internal Resource Costs	Internal resource rate has been amended to reflect our new structure enabling it to be reduced to [redacted] day.
External Resource Costs	Continue to negotiated rates with potential suppliers and where appropriate use existing Framework Agreements with our key suppliers (which we re-negotiate on a regular basis to ensure ongoing value for money) leveraging SHE Transmission's buying power.
Build Costs and Running Costs	A suitable route to market for procuring the modular substation equipment will be developed, this could include a competitive tender process or use of SHE Transmissions existing Framework Arrangements. The MASC project is only looking to fund the additional cost for the first time deployment.
Selection of the Transformer	The costs have been based on a trial site which will utilise a 60MVA rated transformer. This is typical of the rating which is required for new renewable connections and also aligns with

	SSEPD substation frame work contract. The selection of the base unit MVA rated transformer will maximise the opportunity use purchasing numbers to drive down costs and also align with larger market potential volumes. The cost of the transformer will largely be out with the scope of the NIC project, unless there are any additional costs associated with the MASC approach.
IT Infrastructure & Support	These are planned to be delivered by SSEPD's IT team, to leverage their buying power to get value for money.

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Appendix 11 Maps and Diagrams

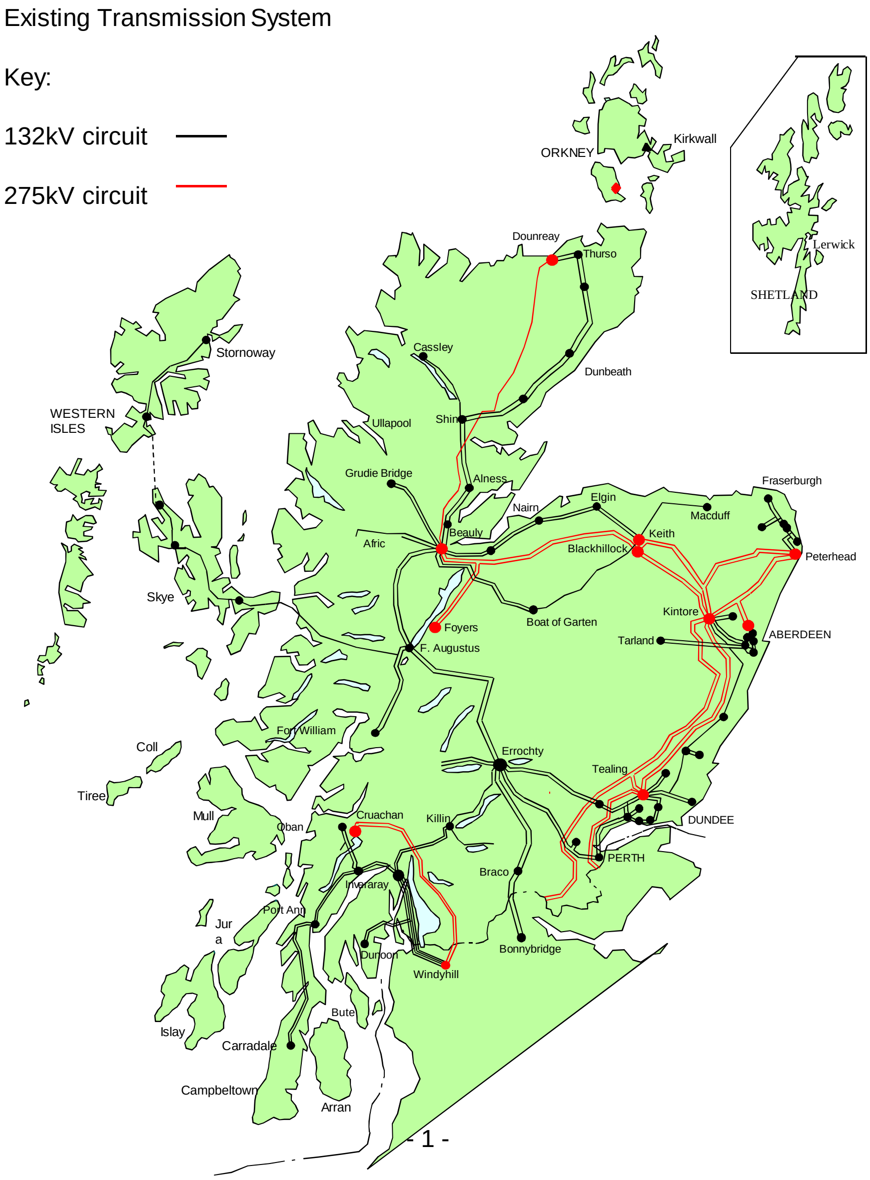

Figure 1 – SHE Transmission Existing Network

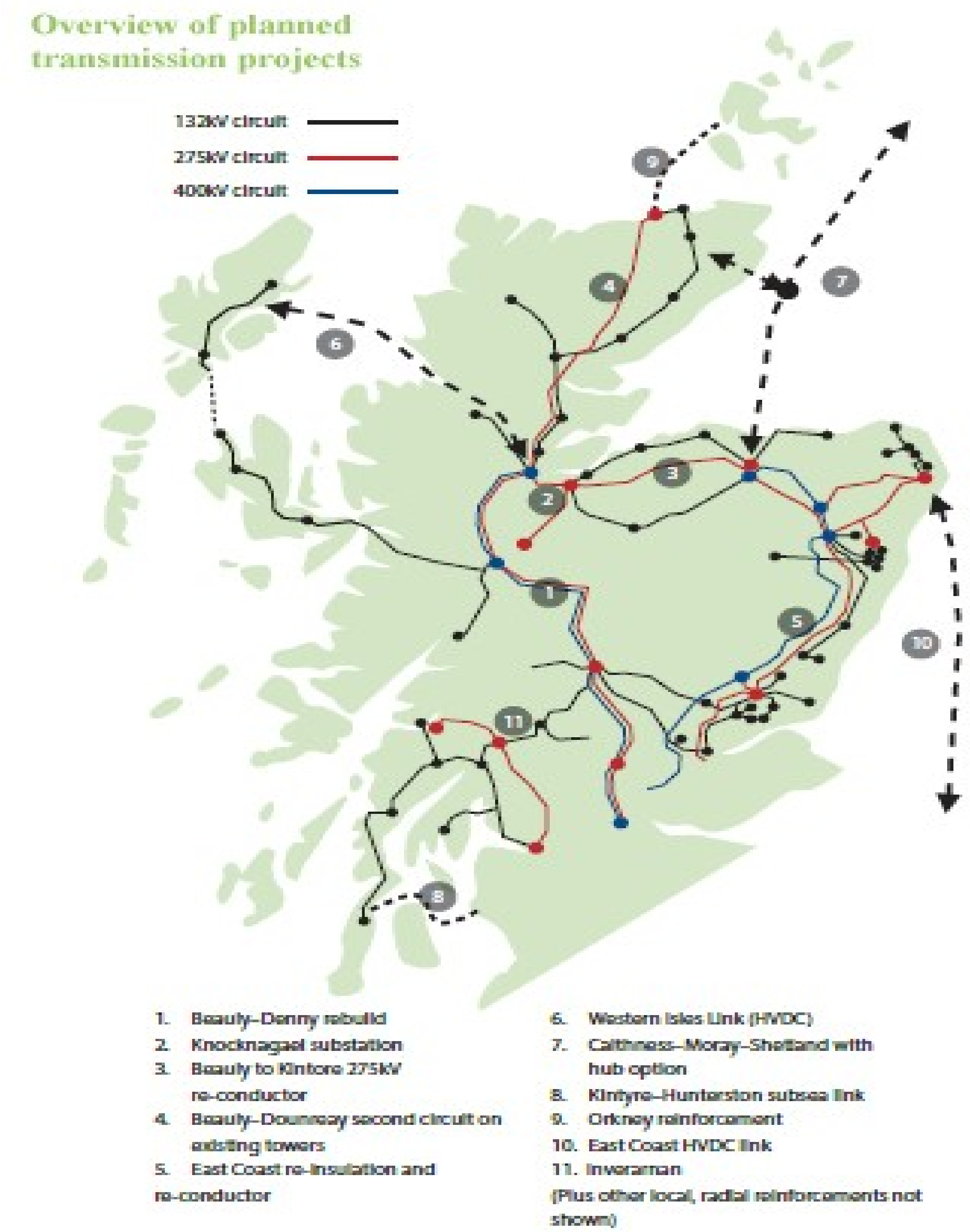

Figure 2 – SHE Transmission Proposed Network

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Appendix 12 – Reference Notes

[1] National Grid's **"Electricity Ten Year Statement"** contains various scenarios for the UK's future. Note that the MASC project has used the 2013 version of this Statement. A new version has been uploaded in July this year, which has not been incorporated into the submission. Details of this document can be found on: http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Electricity-ten-year-statement/

[2]The Institute of Engineering and Technology's position statement, **"Handling a Shock to the System"** (2013), can be found here: http://www.theiet.org/factfiles/energy/elec-shock-page.cfm?origin=myc-pnjv

[3]The UK Government's "**Carbon Plan**" (2011) can be found here: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47613/3702-the-carbon-plan-delivering-our-low-carbon-future.pdf

• National Grid's "**Transmission Entry Capacity (TEC) Register"** can be found here: http://www2.nationalgrid.com/UK/Services/Electricity-connections/Industry-products/TEC-Register/

• Taken from the SHE Transmission Business Plan (2011), which can be found on through the following link. Please note that this plan is updated on a regular basis and information used for the submission may change in alignment with business and regulatory requirements: http://www.ssepd.co.uk/TransmissionPriceControlReview/

† An example of a Transmission Charging Statement, published by all TOs, can be found here: http://www.ssepd.co.uk/Library/ChargingStatements/SHET/

‡ The European Commission's document setting out targets for the connection on renewables can be found here:http://eur-lex.europa.eu/legal-content/EN/ALL/;ELX_SESSIONID=pStnTTPMjC6yQQkJ5pGNwV22yqnyTNxC6SyrBvbSxfFPNyCT3T6H!-1955458796?uri=CELEX:32009L0028

* The System Operator Transmission Owner Code 2004 can be found here: http://www2.nationalgrid.com/UK/Industry-information/Electricity-codes/STC/The-STC

Appendix 13

NIA-SHET_0013 Modular Approach to Substation Construction – Design Development

The Project Plan

SHE Transmission opened a Network Innovation Allowance project to explore the potential for a generic functional specification; the following objectives are complete.

- ü Engagement with Original Equipment Manufacturers to identify potential innovations which may be selected for the generic functional specification.
- ü SHE Transmission internal workshops have taken place to identify potential opportunities and challenges and to clarify the scope of the modular substation specification.
- ü SHE Transmission internal engagement event has secured our internal stakeholders' understanding and positive view on the modular approach.
- ü A list of potential sites has been considered and selected and a short-list has been created.
- ü An external resource ([redacted]) has been contracted to evaluate possibilities for the final functional specification.
- ü Coverage of the project so far has been prepared for this year's Low Carbon Networks and Innovation conference, which takes place in October in Aberdeen.

Possible innovations

A number of potential innovations have been identified during SHE Transmission's engagement with the supply chain and other stakeholders within the NIA-SHET_0013.

On the civil engineering innovation front there might be an opportunity to use screw pile foundations. Also the design of the structure enclosing the electrical equipment, temporary access roads, prefabricated bunding, and methods to support income and outgoing connections may also be considered if appropriate.

The 'plug and play' solution which may be used on the protection and control wiring is very much a transferable concept. A solution reducing the number of wires associated with the protection and control schemes may also be offered this could include solutions such as Bay controllers and process bus architectures. The application of wireless communications and fibre based communications media may be a feature of the final solution and are clearly applicable to a wider range of scenarios than those being evaluated in MASC.

SCADA equipment and its subsequent commissioning are time consuming and normally installed towards the end of the onsite installation period. Supply of the necessary equipment to the factory will be explored, to enable inclusion within the factory installation stage and an element of pre-commissioning.

When looking at auxiliary services it is normal to supply AC and DC voltages MASC may provide an opportunity to stream line auxiliary supplies, the time taken to evaluate, monitor and learn about alternatives shall be beneficial to all subsequent projects.

Above is a small selection of possible innovations which have far reaching potential benefits. But the key to realisation is in the opportunity and time to demonstrate in the field, collect supporting information, and provide analyses to support recommendations. The MASC project intends to apply a number of these new innovations together to provide a 'step change' in design and construction practise.

The NIC funding will provide the necessary vehicle to ensure that the maximum benefit from the MASC trial is incorporated into 'business as usual'.

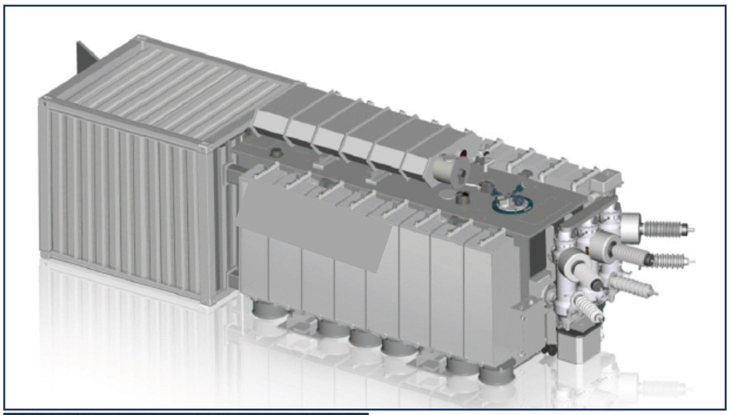

Figure 3 Examples of possible innovations to be included in the MASC functional specification: modularisation, off-site fabrication and commissioning techniques, and screw pile foundations respectively.

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Appendix 14 – Resource Plan

This plan describes the man-days required for internal and external resource throughout the project.

People to be confirmed	**Days Required in Year 1 (to Mar 2015)**	**Days Required in Year 2 (to Mar 2016)**	**Days Required in Year 3 (to Mar 2017)**	**Days Required in Year 4 (to Mar 2018)**	**Days Required in Year 5 (to Dec 2019)**	**Total Days**
External Support Technical (Substation)	15	192	230	182	26	**645**
External Support Technical (Non-Substation)	5	20	50	50	20	**145**
TOTAL	**20**	**212**	**280**	**232**	**46**	**790**