Project MSB
Mobile Substation Bays

Project Code/Version No:
NGETEN01/v2

Project Code/Version No: NGETEN01/v2

Electricity Network Innovation Competition Full Submission Pro-forma

Section 1: Project Summary

1.1 Project Title:

Mobile Extra High Voltage Substation Bays - 'MSB'

1.2 Funding Licensee:

National Grid Electricity Transmission Ltd

1.3 Project Summary:

The Government's aim, expressed in the Carbon Plan, is to run a 'race' between low carbon electricity generation technologies. As a result, the massive investment in the GB electricity transmission system needed to enable a low carbon electricity system, has to be planned against a backdrop of substantial uncertainty around, where, when and what proportions of intermittent, base-load and flexible generation will connect to the network.

Developing a flexible solution to substation capacity that may only be needed for relatively short (in transmission network terms) periods will add a valuable new option for a wide range of uncertainties that all GB transmission networks face.

This project will design, develop and demonstrate a 400kV mobile substation bay to overcome the challenges that currently render the deployment of temporary capacity within transmission substations uneconomic.

This project will:

- Develop and demonstrate the deployment of a 'first of a kind,' rapidly deployable and removable mobile substation bay in a live substation on the GB 400kV transmission network.
- Develop and evaluate the deployment methodology which can enable re-use and deliver operational and financial benefits to Transmission customers and overall savings to electricity consumers.

The project will start in April 2014 and conclude in June 2018.

1.4 Funding

1.4.2 NIC Funding Request (£k): 8,401.38

1.4.3 Network Licensee Contribution (£k): 1,542.23

1.4.4 External Funding - excluding from NICs/LCNF (£k): 590.44

1.4.5 Total Project cost (£k): 11,818.13

Electricity Network Innovation Competition Full Submission Pro-forma

Section 1: Project Summary continued

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

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

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

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

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

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

Project partners

National Grid is currently undertaking a competitive process to select either:

- A substation Original Equipment Manufacturer (OEM)
- Other solution providers that may be a consortium of specialists

External Funding

The selected partner will be encouraged to contribute through the provision of background IPR and equipment design & development costs.

Project Support

This project is supported by both of the other onshore Transmission Owners, Scottish Power Transmission and Scottish Hydro Electric Transmission and The Carbon Trust (letters of support are included in Appendix 6).

1.7 Timescale

1.7.1 Project Start Date:	**1.7.2 Project End Date:**
April 2014	June 2018

1.8 Project Manager Contact Details

1.8.1 Contact Name & Job Title: Ray Zhang Protection & Control Technology Leader	**1.8.3 Contact Address:** National Grid House Gallows Hill Warwick CV34 6DA
1.8.2 Email & Telephone Number: ray.zhang@nationalgrid.com 07786 114 258	

Electricity Network Innovation Competition Full Submission Pro-forma

Section 2: Project Description

Background

(Pictures of examples of all of the following high voltage substation equipment are given in Appendix 8: Substation site pictures)

A **substation** is a node on the Electricity Transmission network which enables power to be directed safely and securely from generators to demand locations. A substation is typically made up of a number of 'substation bays' which connect together circuits, generators and demand. Substations are designed and operated in different configurations, to provide high levels of supply reliability and security. There are over 300 transmission substations in England and Wales alone. The major components operate at extra high voltages 400,000 volts (400kV) and 275,000 volts (275kV), consequently the switching equipment and transformers must be physically large and robust to endure the duty and operational environment. Manufacturers of transmission equipment supply a global market that requires substation equipment to have operational lifetimes of 40 years or more.

Switchgear is required to connect transformers and circuits to the network and disconnect them for maintenance or if a fault occurs.

Transmission **transformers** are large (up to 300 t installed weight) and very efficient (around 99.8%) electrical devices that convert electricity at the transmission voltage (400kV or 275kV) to the primary distribution voltage (normally 132kV). This enables the efficient transmission of electrical power. A typical transmission transformer (also called a SuperGrid transformer or SGT) can supply 240 MW (240 million watts, enough for a large town or equivalent to 80,000 3kW kettles). These transformers are also designed to limit the current that flows when there is a fault in the network and to control the primary distribution voltage. The transport weight of a transformer (around 200 t with the trailer) means that special arrangements, permits and sometimes expensive highway reinforcements are required for transport. Once on site, they are filled with mineral oil, and require extensive concrete foundations with oil and fire containment facilities. Installation typically takes 10-20 weeks, but the costs and timescales are justifiable over a long anticipated lifetime. Multiple transformers are required at each substation to allow for maintenance and failure without losing supply.

National Grid has a spare SGT that has been specially designed to split into three parts in case emergency replacement is prevented by transport restrictions. This transformer is more expensive, less efficient and has a lower resistance to damage from solar storms than normal. It requires the full foundation and installation of a normal transformer.

Protection and control (P&C) provides a means of measuring voltage and current to detect problems and operate the switchgear if required and this must be integrated into the rest of the substation systems to provide coordinated operation of the substation bay.

A **substation bay** consists of a combination of high voltage and low voltage switchgear, a transformer and protection and control, which together are required to connect a renewable energy generator or a distribution system to the transmission network.

Project Description continued

The concept of mobile or temporary bays which can be quickly moved is not new. Mobile substation bays (MSB) have been widely used at lower voltages, typically up to 145kV. This is principally because the equipment is intrinsically lighter and more compact and transportable than that required for the transmission system. More recently, as renewable energy has started to proliferate, the application of quickly deployable and mobile bays at higher voltages has started to occur and there are applications at voltages up to 300kV. Appendix 7 lists a selection of mobile bay applications around the world. There is however, no application of a rapidly deployable temporary bay at 400kV installed by any utility. There are examples of individual components such as the transformer or switchgear, but not the combined solution for 400kV. The original equipment manufacturers (OEM) are developing solutions, however these are still in the design stage.

2.1 Aims and Objectives

Purpose

This project aims to test the feasibility and economics of rapidly deployable substation capacity, using alternative design and installation strategies. The expectation is that this will significantly reduce construction timescales for temporary capacity enabling more flexible and efficient capital delivery and maintenance.

Proving feasibility at 400kV will provide National Grid and the other Transmission owners with the confidence to pursue this as an additional method to deliver flexible network capacity. This method of quickly deployable temporary capacity could be used to:

- Free up outages or remove constraints, to facilitate equipment maintenance or replacement.
- Utilising different construction options to reduce the cost of network reinforcement or asset replacement.
- Quickly provide temporary capacity to manage temporary changes in network conditions.
- Positively benefit customers by connecting renewable generation earlier than currently possible and move demand security to facilitate more efficient network development and replacement.
- Establish lower cost short term contracts.

Scope

The MSB project will develop innovative solutions suitable to provide the functions of a 400kV substation bay, this will include rapidly deployable and connectable:

- Switchgear Bay.
- SuperGrid Transformer (SGT).
- Protection and Control functions.

This will require the development of different deployment methodologies and associated procedural documents such as:

- Technical policy, specification and application guidance.
- Work procedures, Safety documents, Operational guidance.

Since the aim of the project is to deliver a solution that is not permanently required on the network, the project also includes exploration and evaluation of alternative commercial, storage, maintenance and ownership arrangements.

Development Strategy

Significant innovation in technology, deployment methodologies and operating procedures is necessary to demonstrate that MSBs will perform on a cost-effective basis at extra high voltage. The project will address these challenges through the following stages:

- Identify business needs and further technology developments for 400kV transmission network applications.
- Define specifications of the proposed solution based on the results of the feasibility assessment currently underway.
- Design, prototype, and test modular mobile substation bay components (e.g. size, weight, installation requirements, electrical performance, reliability).
- Develop the new procedures, safety rules, installation and commissioning processes necessary for implementation.
- First deployment and demonstration trial in an extra high voltage transmission environment (400kV) in GB.
- Removal from first site, re-test, service and re-deployment to second site.
- Investigate commercial arrangements for different ownership, lease and service provision options.
- Evaluate cost, system wide benefits and business case for an optimum roll out of MSBs across GB for all TOs.
- Dissemination of the learning to the Electricity Supply community at all relevant stages of the project.

2.2 Technical description of Project

The 400kV MSB demonstration will involve the design, manufacture, testing and demonstration of a MSB with the following components (fig. 2.1 illustrates):

- 400/132kV transformer.
- 400kV & 132kV switchgear (circuit breaker, disconnector and instrument transformer), necessary to safely connect the transformer to the substation busbars and customer's substation.
- 400kV & 132kV busbar, conductor & cable necessary to connect the MSB components into the substation busbars and the customer's substation.
- Protection and control functions to provide reliable & remote operation.
- Quick deployment transportation rigs.
- New safety and operational procedures.

Project Description continued

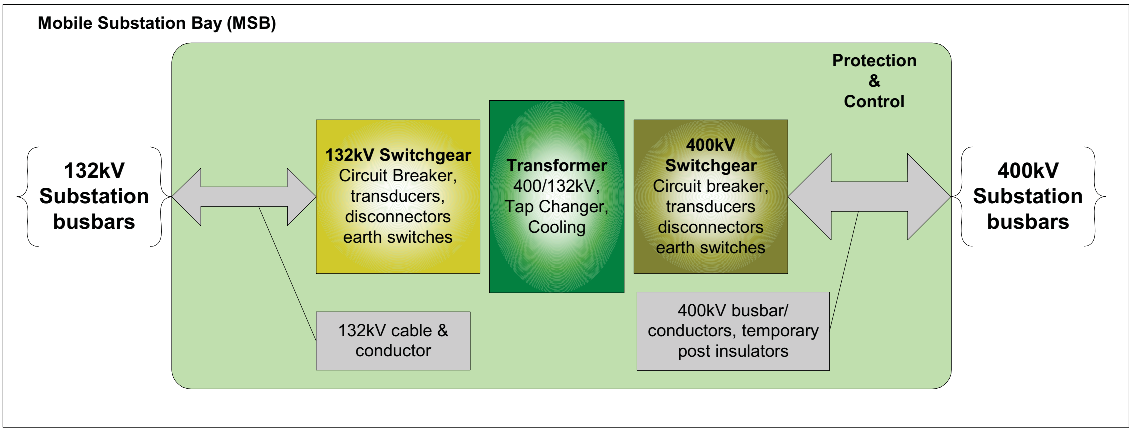


Figure 2.1 Components of a Mobile Substation Bay

There are a number of key innovative elements to the MSB project, from design and development of new equipment, to the development and adoption of new procedures and processes for implementation business as usual. The objective is to significantly reduce construction activity from typically 20 weeks to less than two weeks.

The MSB will be primarily used to meet short term operational needs, typically between 3-18 months, rather than 40 years. At the end of this it will be relocated to the next site that needs it.

This will enable a new design philosophy and asset management strategy.

Design Innovation

The GB transmission network is a very complex and integrated system and is probably one of the most meshed networks in the world. Most of the maintenance and construction work on the system is bespoke: each substation has its own set of unique requirements (customers, environmental challenges, amenity requirements and topology).

The design principal behind the Electricity Transmission system is to securely and reliably deliver power to GB customers and is based on permanent long life installations typically designed to operate for 40 years or longer. This is based on having a predictable and stable future load profile. The increasing penetration of renewable energy and smartgrids at the distribution level requires a more flexible approach to transmission network design and operation.

This application will be the first of its kind at 400kV, and will enable Transmission Owners to more efficiently manage outages and connect new customers faster than has historically been the case. The functional performance will concentrate on designing, testing and using equipment which can;

- Be transported on normal heavy goods transportation - Category 2 transport requirements (<80T and <30m long), removing the need for special transport permits.
- Have a rating of >100MVA.

- Be deployed & commissioned within two weeks. This is based on having three weekends available for outages to access the system and carry out commissioning activity.
- Remove, or at least minimise, the need for cranes by employing self installing systems.
- Remove the need for any significant permanent civil construction (leaving a zero legacy footprint) for example using removable fixtures such as temporary foundations and structures.
- Use 'Plug & play' control and protection.
- Be decommissioned and removed in less than two weeks.
- Be suitable for storage or redeployment to another site within two weeks.

Technology innovation

The MSB project will include the development of;

- Low weight transformers, incorporating low fire risk materials.
- Lightweight transport structures for example removable transport bogeys for fast self installation.
- Temporary transformer fire and oil containment removing the need for permanent concrete foundations and buildings.
- Rapidly configurable compact pre-assembled 400kV switchgear, for example hybrid switchgear.
- Protection & Control that is readily transportable, easily installed and interoperable with the various P&C functions already embedded within the existing system.

Innovation in process and procedure

Most of the global experience of using mobile substation bays is in the context of complete new sites. The great challenge for GB TOs is to safely apply these ideas and processes in the context of an existing substation environment. The successful application of the MSB will require a change of thinking around the logistics and procedures necessary to support a quick deployment and temporary application, rather than a permanent 40 year long installation at 400kV. This will require the development of revised methodologies regarding:

- Maintenance (this will always be offline for MSBs – between deployments).
- Safety rules and documentation for operation in the vicinity of MSBs and integration into an operational substation environment.
- Commissioning programmes.
- Control room procedures to use equipment remotely.
- Operational procedures.
- Self installation where possible.
- Procedures for 'hook up' to site services and integration into site safety functions.

2.3 Description of design of trials

The project will demonstrate the proof of concept through a real trial application in a live substation environment.

The MSB will be installed next to a normal bay in an operational substation. This will enable the team to quantify and evaluate the risks and benefits of the MSB approach, through comparison of the various logistics, costs and implementation time scales. There will always be some site specific elements; however the guidance produced as part of the project will aim to address the generic issues.

Phase 1 – MSB design feasibility (Apr 2014 - Mar 2015)

Objective: The degree of engineering and logistics associated with this project is very high, significant effort will be directed at the development of specifications, procedures and supplier selection. The functional specification for the MSB, will be developed by technology workstreams using expertise from across teams in National Grid which will be impacted by this change of approach.

External market research is currently being carried out looking at relevant areas of technology and logistics associated with making transmission equipment lighter, more compact and mobile.

National Grid has internal governance processes which will be used to approve the documentation so that the manufacturing and construction phases can proceed. A selection of candidate deployment sites has already been identified. The final decision about first deployment and re-deployment sites will be made as the documentation preparation phase is taking place.

The supplier selection process is already underway to establish interest, capability to deliver and potential to contribute to the project. The MSB specification and deployment sites will need to be available for the tender process to assess supplier capability and deliver value for money. This phase will conclude with confirmation of the equipment suppliers.

Deliverables: The key outputs of this phase will be technical and procedural documentation.

- The specifications (transformer, switchgear, protection & control, transport unit).
- Revised work procedures (safety rules, operational procedures).
- Agreed deployment sites
- Signed contract with supplier(s).
- Finalised detailed designs.

Phase 2 – MSB development, manufacture & testing (Nov 2014 - Mar 2016)

Objective: This phase concentrates on the detailed design and development of the MSB equipment based on the functional specifications produced in Phase 1. This phase will primarily be delivered by the major OEM partner. It is intended that they will fund the detailed design (thus retaining IPR).

Once the design is approved, manufacturing and testing of the MSB components will commence. The fabrication of the transport and support infrastructure necessary to carry and house the equipment during transport to site, operation and then relocation will be key aspects.

Deliverables: The mobile MSB fully constructed & tested, including the transformer, switchgear and protection. The units will be then made ready for transport to site.

Phase 3 – 1st Deployment (Sept 2015 - Dec 2016)

Objective: The MSB will be installed and operated in a live 400kV substation. Subject to the new design passing factory acceptance testing, it will be transported, installed and commissioned under the new procedures. This will establish the degree to which the installation time can be reduced and identify areas for improvement/revisions to the equipment design and the procedures.

Deliverables: MSB fully commissioned at Site A and control handed over to the Transmission National Control Centre (TNCC).

Phase 4 – Redeployment (Jan 2017 - Dec 2017)

Objective: This stage will involve decommissioning the MSB and then returning it to the stores where it will be inspected and refurbished (if necessary) and then prepared for transportation to the next site. The redeployment site will require preparation to receive the MSB. Installation and commissioning at site B, review and revision of procedures to include new learning from the relocation activity.

Deliverables: Site A fully decommissioned, inspection and refurbishment of the MSB, redeployed MSB at site B, commissioned and handed over to TNCC for operation.

Phase 5 – Learning and Dissemination (Apr 2014 - June 2018)

Objective: As the project progresses the proven cost and financial and carbon benefits will be regularly re-evaluated to inform a national roll out strategy. This will also consider novel commercial arrangements for the ownership and maintenance of MSBs (own/loan/lease). Further information about dissemination is presented in section 5 and is not reproduced here.

Deliverables: Commercial Options Report, GB National Rollout Plan.

2.4 Changes since Initial Screening Process (ISP)

There are no material changes to the ISP, however some points which have been clarified since the ISP include:

- The procurement process has commenced and will be complete by Dec 2013, with a view to having contracts to sign in April 2014.
- The deployment sites will be confirmed by April 2014 and the first deployment will be installed at the latest by Dec 2016, with the first redeployment being complete by December 2017 and project closure June 2018.

Electricity Network Innovation Competition Full Submission Pro-forma

Section 3: Project Business Case

3.1 Introduction

The objective of this section is to explain the range of likely situations in which MSBs could offer benefits, and estimate the value of these benefits to customers and the consumer.

The MSB demonstration project itself is expected to have a higher cost (contingency, risk mitigation and removal costs) than the current business as usual method, however savings will be possible when the demonstration MSB is re-used on the next application.

This analysis considers the potential benefits of MSB on a typical substation construction scheme and compares the current best options with the MSB approach. This analysis shows that if a proven 400kV MSB with at least 100MVA rating was available, it would probably be economically viable; however, NIC funding is required to cover the financial risks from first deployment and the uncertainty of achieving the anticipated rating and the full range of anticipated benefits. Typically, the greatest benefit from MSBs will come from deploying to support short to medium term complex construction and maintenance activities associated with congested and constrained parts of the network. Therefore if successfully implemented both cost savings and better network access should be achieved.

3.2 Business Drivers

Future system requirements indicate a need to be more flexible and accommodate new customers. The nature of the system will change as the percentage of intermittent renewable generation and active embedded networks increase and replace the traditional type of generation the network was designed to accommodate in the 1960s and '70s. These new types of generation will require the transmission system to be more flexible and responsive to changing conditions and topology.

This is further complicated by the uncertainty around, where, when and in what proportions intermittent, base-load and flexible generation will connect to the network over the next two or three decades.

The NIC was established to support this kind of proposal, which is far enough along the technology readiness scale yet retains sufficient uncertainty and risk of failure for a Transmission System Operator.

- This is an innovative application using new technology and concepts for temporary use at the transmission level.
- There is uncertainty around **how quick and mobile** it is possible to make a 400kV bay with a meaningful rating.
- The technology application is new to transmission and not a standard business deliverable.
- Using this technology would be a shift from the existing risk appetite in the industry.
- It will be beneficial to prove the technology for the wider UK energy industry.
- There will be savings for customers and consumers in the long term, but the concept needs to be proven first.

3.3 Scenarios in which MSBs are foreseen to be beneficial

Load related driver:

- ***Temporary Connections:*** MSBs could be used to provide a capacity service for either generation or demand connections for a short duration while a permanent substation is built or 'end of life' is extended for a couple of years. The potential benefit directly for customers is facilitating the energy market, reduced constraint costs and risk of stranded assets.

Non-Load related drivers:

- ***Securing demand during SGT Maintenance*** ("N-2" requirement): The availability of one or more MSBs to secure the N-2 security standard (in the event of a failure) could potentially defer SGT investment for the extra capacity required.
- ***Failure Recovery***: The MSB will add a valuable rapid supply restoration capability in the event of extreme events causing failure.
- ***Efficient asset replacement:*** The MSB may make it possible to carry out an in-situ Air Insulated Switchgear (AIS) replacement programme of an end of life AIS substation and avoid the need for what is know as off-line Gas Insulated Switchgear (GIS) build. This could be achieved either by offering more flexibility around the current, time consuming option, of bay-by-bay replacement, enabling the bypass of problematic circuits or allowing larger sections of substation to be switched out without reducing supply security.

These scenarios are further illustrated in Appendix 11.

n3.4 MSB demonstration benefits

Based on the list of schemes that are being considered for the NIC demonstration project, it appears likely that it will be considered on a scheme where it will be used to secure demand during SGT maintenance. The benefits in this scenario are described below.

The example compares the two different methods to deliver transformer capacity on a 400kV demand connection. The first addresses the current business as usual approach and this will be compared to the MSB option. The difference between the costs associated with a permanent build solution (current practice) and that which would be expected for a temporary installation using the MSB are primarily related to the construction costs for civil foundations and the project duration to deliver this permanent infrastructure. The challenge is to account for the temporary nature of the application.

Current practice

Customer demand is met using a 400/132kV transformer capable of supplying 240MW. Transmission network infrastructure is designed using robust and reliable equipment installed on a permanent basis typically for 40 years or more. This is to ensure the equipment can achieve this expected lifetime or longer and withstand a range of onerous conditions during its lifetime and be appropriately maintained in a safe and reliable manner.

This requires permanent civil constructions such as large concrete plinths, oil bunds and fire walls to house the equipment and to protect the environment from oil leaks, fires etc. These costs vary significantly depending on the ground conditions and environmental conditions the range can be between [redacted] per installation and will add up to 10 weeks to the programme.

This type of transformer weighs up to 200 tonnes when full of insulating oil. This requires very special transport needs and lifting equipment, requiring road closures, bridge reinforcement and special permission to get the equipment to site. Transport to site can add on average [redacted] installation and necessitate special permits to use the highway.

These design features are not conducive to a fast or rapid deployment strategy and a typical installation will take up to 20 weeks. This is particularly problematic if there has been an equipment failure and security of supply or circuit reliability is compromised or if the transformer is only required for a few weeks to cover a maintenance condition.

Mobile Substation Bay Alternative

The design and development of a more flexible and mobile bay which can be quickly installed and readily moved and relocated within 2 weeks will enable National Grid and other transmission utilities to establish a temporary capacity capability which can be much more responsive and accommodating to address transmission short term requirements. There are a couple of fundamental differences which need to be considered with temporary or mobile applications.

The key potential savings associated with this concept include:

- Significant savings on civil requirements in the range [redacted] per installation on difficult sites
- Less time on site – reducing resource costs around installation and commissioning – in the range [redacted]

However, the MSB is likely to involve compromising certain performance characteristics:

- It is unlikely a 240MVA rating will be achievable in a rapidly mobile unit in order to meet transport requirements, so net benefits calculations assume that 100MVA is achieved.
- Uncertainty around how many times the MSB can be redeployed, for benefit calculation purposes we assume 10 times.
- It is uncertain what the total operational life of an MSB transformer will be. We are currently assuming 10 years.

Further details about the assumptions used to inform the benefits case, and the reasons behind them, are contained in Appendix 10 'Base & method cost details'.

The evaluation compares the costs for three scenarios which are summarised in table 3.1.

Project Business Case continued

Scenario	Cost Range (£)	P50 cost (£)	Benefit compared to BAU (£)	Comment
240MVA Permanent Transformer (BAU) – Typical installation	[redacted]	[redacted]	[redacted]	Used for base case
NIC MSB Demonstration	[redacted]	[redacted]	[redacted]	Includes 1st redeployment to test proof of concept
MSB employed as business as usual alternative to 240MVA transformer bay.	[redacted]	[redacted]	[redacted]	

Table 3.1: MSB Demonstration Example Cost Benefit Analysis

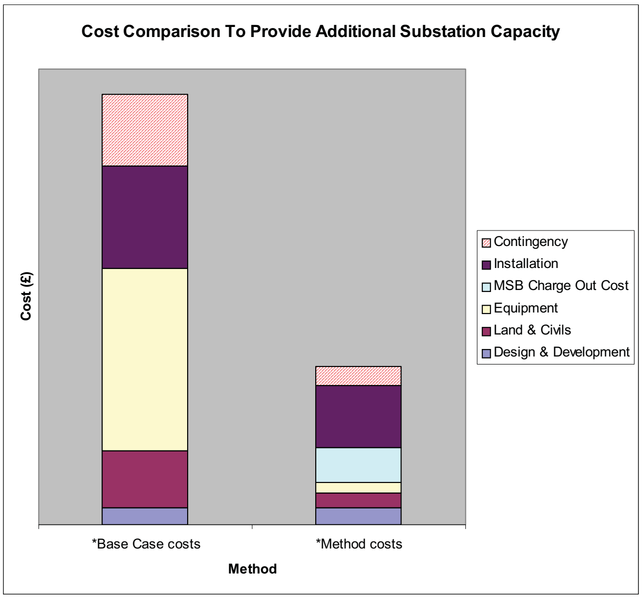


Figure 3.1: Graphical illustration of potential MSB benefits when used to maintain security during SGT maintenance.

(For further information about the assumptions and sources of data please refer to Appendix 10.)

3.5 Benefits of MSB roll out Wider

The wider roll out will require a fleet of MSBs to deliver the potential benefit. Table 3.2 identifies some of the benefits which incorporates the cost of the additional bays in the evaluation. The estimated development cost for the MSB is in the range of [redacted] and it is hoped that if successful this cost could be reduced to approximately [redacted] for the initial equipment purchase and then deployment costs of [redacted] each time.

Temporary system access and capacity

The rapid provision of temporary capacity would provide system access while permanent capacity is being constructed, thus allowing generators to access the market earlier. This would require some commercial agreements around unsecured capacity. This could be as much as 12-18 months, depending on the generator's construction programme. As an example connecting a 100MW wind farm with a load factor of 30%, 12 months earlier than currently possible would result in an additional energy delivery of 263GWh at [redacted] and 117,000 tonnes of carbon saving (based on the 2013 emission factor for grid average electricity published by DEFRA of 0.445 kg/kWh). This would benefit directly connected customers by providing additional revenue.

Efficient asset replacement.

The MSB could help to free up space to enable more efficient build options in particular when replacing end of life switchgear. Approximately 90% of substation extensions and replacements result in new construction using Gas Insulated Switchgear (GIS) which is much more expensive than the equivalent Air Insulated Switchgear (AIS). The MSB could help to facilitate an AIS replacement in less than half of the time it would take to using current single bay-by bay procedures. This could substantially reduce the need for offline GIS build option, which provides a twofold benefit: lower overall cost and reduction in SF_6 usage.

Application	Scale (£)	Prob (%)	Assumptions	Risk discounted benefit in (£)
(i) Temporary connections for renewable or embedded generation - Requires 1 MSB at a cost of [redacted]	[redacted]	50%	Customer: connection 12-18 months early while permanent access and capacity is under construction. [redacted]	[redacted] per application
(ii) More efficient asset replacement. Avoid expensive offline GIS substation construction. Assumed to require 2 MSBs	[redacted]	50%	52% of capital savings shared with consumers	[redacted] per application

Table 3.2: Customer & Consumer Benefit Analysis from Additional MSB Applications (further information about what these figures represent is provided in Appendix 11)

3.5 Technology & commercial risks

The major risks for the roll out of MSBs are whether it can be safely deployed with acceptable environmental and reliability performance. The cost of mitigating actions to address transport disruption, oil containment, fire, acoustic noise etc can easily cost in excess of [redacted] per installation. These will continue to be employed on permanent installations with lifetimes of 40 years or longer. The estimation of the financial benefits identified above assumes that these costs can be significantly reduced for temporary installations.

Protection and control occupies a lot of engineering resource and can be the major obstacle to swift installation, often requiring many outages to safely integrate and test the various operational configurations. This project seeks to provide the minimum necessary level of protection & control to reduce this impact, while still providing sufficient security and dependability to safeguard power system stability and reliability.

Many of the potential applications will connect into double busbar substations. SQSS Design guidelines require the connection to both bars to provide operational flexibility over the lifetime (40 years) of the substation. Since this is only a temporary application (typically 3-18 months), the MSB will only connect to one of the busbars, introducing an operational limitation and reducing the degree of flexibility compared to that of a fully operational substation.

Further information about the level of technology readiness for the main elements that will make up a 400kV mobile substation bay is contained in Appendix 11.

Electricity Network Innovation Competition Full Submission Pro-forma

Section 4: Evaluation Criteria

This section outlines how the mobile substation bay strategy would benefit customers and the wider community should it prove to be successful. The assessment is broken down to consider how the MSB will address a range of criteria namely:

- Benefits the low carbon agenda
- Provides value for money to consumers
- Generates knowledge that can be shared
- Demonstrates innovation
- Brings in partners and external funding
- Is relevant and timely.

4.1 Accelerating the development of a low carbon GB energy sector and delivering other environmental benefits

'[It is] impossible to predict which will be the most cost effective route [to decarbonisation of the electricity sector] and what the power generation sector will look like in 2030'. p73 The Carbon Plan.

The Government's aim is to run a technology 'race' between different low carbon power generation options. To facilitate this, new and innovative approaches to developing the transmission network are needed to keep options as open as possible in a cost effective way, and to be able respond swiftly as the future generation mix and locations become clear.

Contribution to reducing greenhouse gas emissions

The Mobile Substation Bay can potentially address aspects of green house gas (GHG) emissions reduction as set out in the Carbon Plan such as:

- Support the management away from SF_6 intensive Gas Insulated Switchgear (GIS). GIS contains much more SF_6 than the equivalent AIS. SF_6 is an extremely effective electrical insulator, however, it is a greenhouse gas 23,900 times more potent than CO_2. The development of a new design option, using MSB's to maintain security of supply during replacement, will enable multiple bays to be switched out at the same time making AIS replacement much faster, reducing the cost, and decreasing the number of occasions when off-line GIS is used. This will not reduce the amount of SF_6 currently in the system, but will minimise any addition to the installed volume.
- The MSB can help connect renewable generation sooner, while also managing the decommissioning of ageing high carbon generation into a network which already has a constrained and complicated upgrading schedule. The MSB could provide temporary capacity while more permanent solutions are constructed. This would result in a carbon dioxide equivalent savings of 117,000 te for every 100MW of low carbon generation that is connected 1 year earlier as a result of having a rapidly deployable temporary solution.

- The use of MSBs will also reduce the carbon footprint associated with the substation itself when compared to the installation of a permanent solution as a result of requiring less civil construction and building work. This will also reduce the legacy impact on substations minimising the sterilisation of land for the future. Reducing the amount of permanent civil structures used in these projects will have a net benefit, as concrete has a large CO_2 equivalence.

Releasing network capacity

The 'Connect and Manage' regime introduced a few years ago has improved the access to network capacity, however external factors such as construction lead times and planning rules still impact on how quickly generation can connect to the network. The successful innovation of MSBs and integration into standard substation operating procedures will provide flexible options for the management of several aspects of the transmission network, specifically:

- The prime function of the MSB will be to provide additional temporary transmission capacity.
- A successful trial could see MSBs available by 2018.
- MSBs will be a valuable additional option to facilitate the transition between retiring generators and new low carbon generators without having to incur the cost of permanent installations which may only be required for the transition period where both old and new generators are operating at the same time. One example where this may occur, could make use of 1 or 2 MSBs over a four or five year period, after which they could be relocated, as an alternative to [redacted] permanent investment.

Expected Customer Financial Benefits

The estimated benefits to customers and consumers are set out in section 3 and summarised in Tables 3.1 and 3.2. This is likely to result in reduced connection and use of system charges once the concept is proven to work and charging mechanisms can be revised.

4.2 Provide value for money to electricity transmission Customers

The project will deploy and re-deploy the first 400kV MSB on sites where maintenance or construction work is necessary. As a result there will be 'direct benefits' which are being used to support the funding of the project. Direct benefits contribute 28% of the expected project costs (total project cost less contingency).

Suppliers of equipment and services are being competitively tendered based on National Grid's normal procurement process. This process will ensure good quality project partners and value for money. The public notification issued in June for the MSB project has attracted expressions of interest from 26 companies from around the world. The second phase of the procurement event is currently underway with responses to the pre-qualification questionnaire expected by the end of August and final tender submissions expected by the end of December 2013.

Evaluation Criteria continued

To ensure value for money the MSB project:

- Has appointed an experienced project manager, with more than 10 year's experience of dealing with contractors and delivering projects effectively.
- Has appointed a buyer from its procurement department to ensure that adequate terms and conditions are put in place with any suppliers to meet the criteria under the NIC governance document and ensure the project is getting the best possible value for money from its suppliers.
- Is preparing functional design specifications for transmission transformers, switchgear and protection and control.
- If more than one Transmission NIC project is successful the Carbon Trust has indicated that they are willing to give a discount with a potential saving of [redacted] to the MSB project.
- Established a governance process within the Project Steering Committee that will ensure that the project continues to deliver value for money to the customers as well as consumers through to its conclusion.

The MSB project is being planned to reduce the risk of exposure to any availability and reliability incentives, therefore no request is made for protection from incentives or penalty conditions.

4.3 Generates knowledge that can be shared amongst all relevant Network Licensees

The concept of mobile temporary capacity is new for extra high voltage transmission networks and the learning from it will be shared with the whole electricity community. This project will generate learning that is key to developing investment level confidence in mobile substation bay technology at 400kV.

The benefits from the project relate directly to reducing the cost of building and maintaining the electricity transmission system that is required for delivering a low carbon electricity sector.

The following specific objectives for new knowledge from MSB are:

- The rating and voltage capabilities that can be accommodated within category 2 highways requirements.
- How much the installation time and cost can be reduced compared to conventional methods.
- How much the operational capabilities of MSB are compromised in order to achieve mobility and rapid deployment.
- The costs and benefits of establishing a national fleet of MSB and how many are required to achieve the optimum benefits for customers.

4.4 MSB innovative and risk

The project so far has an unproven business case where the innovation risk warrants development to demonstrate its effectiveness.

- Mobile Substation Bays have not been developed or deployed on any other 400kV network in the world.
- New procedures and operational practices are required and need to be tested.

In order to achieve the benefits of mobility, rapid deployment, and subsequent relocation, at transmission voltages, it will be necessary to make major changes to long established and internationally agreed performance criteria for transmission substation equipment. Review of work done in this area around the world indicates that an application at this scale at this transmission voltage has not been attempted before. The nature and consequences of the changes required are therefore not fully understood. The replacement of any asset on the Transmission network up to date has been approx 20 weeks and in terms of relocation, 6 months is typical.

Process, safety rules and operational procedures related to substation installation, maintenance, replacement and operation are based on international standards and best practice. These are limiting factors in the effective use and deployment of temporary bays. This project will be the first of its kind to develop the alternative processes and documents and will require the risks from such changes to be thoroughly assessed.

4.5 Involvement of other partners and external funding

National Grid's Approach to NIC projects & MSB

Throughout 2012 National Grid organised a number of workshops and bilateral discussions with representation from across National Grid, suppliers, existing and potential new collaboration partners. The aim was to assess the challenges likely to be faced in the RIIO-T1 period and beyond. From this process a long list of challenges and innovative ideas was collated.

Throughout, awareness of the NIC and NIA was raised with all parties and links to the relevant parts of Ofgem's website provided as a source of further information.

In the autumn of 2012 the Innovation Team screened 43 proposals (across Gas and Electricity Transmission) to remove any that were deemed unnecessary duplication of work known to have been done already. The remaining projects were evaluated by a selection of technical and business leads to assess their priority in terms of potential to deliver value and their relevance to the timing of the challenges. Four Electricity Transmission projects that met the criteria for NIC were shortlisted and finally two, MSB and Medici, were approved for development for the 2013 Electricity NIC and submitted in April at the ISP stage.

The concept for MSB emerged from a competition that National Grid ran with suppliers and contractors in 2012. The competition challenge at the time was to submit innovative proposals to reduce the cost and constraint impact of transmission system access for undertaking construction and maintenance work. The ideas submitted were varied and all had aspects that had potential. Further consideration within National Grid identified that the most beneficial outcome would most likely contain a combination of elements of many of the proposals. This has led to the development of the MSB concept and this NIC proposal.

MSB Partners

The MSB project will be delivered with the assistance of two partners.

The first, the Carbon Trust was identified early in the process as holding a unique position to support National Grid's NIC projects as widely recognised and trusted independent experts in the field of low carbon technologies and carbon impact evaluation. The second will be one of the 26 companies that are participating in the ongoing procurement event.

The Carbon Trust

The Carbon Trust is a world-leading organisation helping businesses, governments and the public sector to accelerate the move to a low-carbon economy through carbon reduction, energy-saving strategies and commercialising low-carbon technologies. Their mission is to tackle climate change by creating a vibrant low-carbon economy that delivers jobs and wealth. They can help organisations put sustainability at the heart of their business strategy and gain a competitive advantage in the market.

The Carbon Trust brings value to each of the three specific roles it has in the MSB project:

- Assessment of CO_2 impact.
- Dissemination of knowledge.
- Independent representative on the Project Steering Committee.

Created in 2001, they have developed into a world-leading and trusted expert in low-carbon issues and strategies, carbon footprinting and low-carbon technology development and deployment. They offer more than 10 years of unparalleled experience in the low-carbon sector.

Since its inception, the Carbon Trust's core mission has been to help public and private sector to reduce their CO_2 emissions and so it has unrivalled experience in helping companies achieve this goal. As a means to maximise CO_2 reduction, Carbon Trust has carried out extensive dissemination of knowledge to a variety of audiences. This has included events, reports, case studies and webinars. Many of these are viewable on their website. Given its status as a not for profit organisation, Carbon Trust will not be in a position to make a financial contribution to the project.

Their role will be to validate whether the carbon benefits potentially identified in this project are achieved through the trial.

Evaluation Criteria continued

The Solution Provider

This project is using a competitive selection process to identify the partner that will design, develop and manufacture the MSB to the meet the functional specifications defined by National Grid for this project. The event is seeking expressions of interest from across the globe and is intended to bring new ideas and practices from other fields of engineering beyond that of the power industry supply chain. New players are being sought, however, it is important that the chosen solution providers are conversant with the risks of working and operating in a live transmission substation environment.

The selection process will evaluate proposals based on criteria which will include:

- Value for money.
- Contribution to the project.
- Agreement to work within the NIC default IPR arrangement.

Relevance and timing

The UK has an obligation to binding environmental targets by 2020.

'The Committee on Climate Change's Renewable Energy Review suggests that we could have over 55 GW of renewable electricity capacity by 2030' p 73 The Carbon Plan.

The project programme aims to have proven the MSB concept to the point of business adoption readiness by 2018. This is realistic and appropriate timing for it to become part of the business as usual toolkit for deployment in the 2020's to support the connection of the anticipated level of renewable generation and maintain system security while wider network construction activity progresses.

Electricity Network Innovation Competition Full Submission Pro-forma

Section 5: Knowledge dissemination

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

5.1 Learning dissemination

The MSB project will generate significant new knowledge that will be of interest and benefit to a diverse audience. We will ensure that all relevant stakeholders are reached by well structured dissemination activities that are tailored to meet the needs of the different interest groups. The MSB will provide knowledge about:

- The rating and voltage capabilities that can be accommodated within category 2 highways requirements.
- How much the installation time and cost can be reduced compared to conventional methods.
- How much the operational capabilities of MSB are compromised in order to achieve mobility and rapid deployment.
- The costs and benefits of establishing a national fleet of MSB and how many are required to achieve the optimum benefits for customers.

Key audiences for the MSB Project

Customers & the wider Electricity Industry: The learning and outputs from this project will be of interest to all the industry participants who will wish to gain a better understanding of one or more of the following:

- ***Transmission Owners (TOs).*** National Grid has already undertaken activity to ensure that all on shore TOs are aware of the proposed project and have received their support for this project. It is possible that the most cost effective roll out for GB could involve sharing MSB capabilities depending on the ownership arrangements that the project will evaluate.
- ***Offshore Transmission Owners (OFTOs)*** will have an interest in relation to landing points for off-shore circuits, and the benefits that mobile transformer and switchgear aspects of MSB offer.
- ***DNOs*** will be interested in understanding how to apply the lessons learned and how to use the tools developed in the project in their networks. The MSB concept is well understood at lower voltages but this project may further encourage its use.
- ***Generators***, in particular those at the lower end of the capacity scale that could benefit from quicker connections, will be keen to understand how MSB will impact their business.
- ***Technology Vendors and Original Equipment Manufacturers (OEMs)*** will be interested in the learning and will encourage the wider application of mobile and temporary bays to enhance network capability, as well as the standardisation and

Knowledge dissemination continued

modular bay solutions.

Consumers: electricity consumers are one step removed from the Transmission network as their day to day dealings with electricity are with Suppliers and DNOs. However, the costs of running the network and funding the NIC are ultimately passed through to consumers, so they will have an interest in knowing that this money is being well spent on projects that have a realistic prospect of leading to lower costs than a business as usual approach.

Industry Groups: National Grid is involved with a wide range of National and International industry groups such as CIGRE, ENTSO-E (the European Network of Transmission System Operators - Electricity) , GO15 (previously the Very Large Power Grid Operators group), EPRI (the Electric Power Research Institute), ITOMs (International Transmission Operations & Maintenance Study) amongst many others, as well as having a network of international bilateral information sharing and collaboration partnerships with Transmission Network owners and operators in various parts of the world. The work that is being undertaken under the MSB project will be of great interest to Transmission System Operators (TSO) all over the world as it seeks to address several aspects that will improve flexibility and reduce costs.

Academic Institutions & Schools: information and knowledge developed through the MSB project will be relevant to the education sector at all levels from Primary up to Universities and Higher Education Institutions. National Grid has an active programme to provide engaging and informative material relevant to the National Curriculum through our School Power initiative. We will use this to disseminate greater awareness of the challenges that we face with our future energy networks and some of the possible solutions which in combination will be deployed to solve them. We have close contact with a wide range of Academic Institutions through our framework agreements with several Universities and they and others will have an interest in access to the data generated by the project and the lessons learned from it.

Government Departments and Regulators: several aspects of MSBs will be of interest to and may require the agreement of, a number of regulatory authorities such as the Environment Agency and HSE. DECC and Ofgem will be interested in understanding the benefits of MSB and how they can be used to support Government energy policy.

Our Approach to Dissemination.

We will use a range of dissemination opportunities and activities to enable each of the different audiences to maximise their awareness of the Problem and the learning derived from trialling the proposed Method to develop a practical and usable Solution. We recognise that engagement with several audiences must enable two way communications. This will enable the Steering Committee to ensure the project is responsive to inputs from key stakeholders. We have described below some of the approaches we will take to dissemination to and engagement with affected and interested parties:

Workshops: several of the work packages will start with more detailed engagement with manufacturers and solution providers to ensure that the output is ultimately useable by all relevant parties. We have already held 3 workshops with OEMs and once the work package leaders are appointed they will organise further workshops at a more detailed level.

MSB Website: This will be the central point for all our dissemination activities. It will be updated with progress reports, results as well as providing information about other dissemination events and links to them. The link to the MSB website will be prominently identified on the National Grid Innovation website www.nationalgrid.com/innovation

Lectures, Conferences and Webinars: we are proposing to hold six formal dissemination events throughout the life of the project. These will include the NIC conferences in years 2, 3 and 4. In addition, we will use managed webinars once a year as a means of sharing information with and hearing opinions from our stakeholders. In the latter stages of the project, we will undertake an informal consultation with key stakeholders to gather views on the trial.

Video Pod Cast, Social Media and Press Releases: National Grid's Communications team will facilitate the production of a series of video tutorials describing at a basic level the nature of the problem, the potential solution and what the project is delivering. We will also make use of social media prevailing at the time to provide regular updates to audiences that find this approach more appealing and useful. The National Grid Press office will also release a number of articles about the project.

Journal Articles and Academic Papers and Industry Conferences: Many of our colleagues are members of specialist associations and we will use them as ambassadors for the project, inviting their members to lectures and demonstrations. Trade journal articles will be prepared by the project team for relevant industry journals. The project engineers will also submit at least 2 papers to IET/CIGRE.

Six Monthly Progress Reports and Closeout Report: the reports required under the NIC governance provide a valuable source of information during and at the conclusion of the project. These will be published on the MSB website as well as being submitted as required to Ofgem and published on the Portal currently hosted by the ENA.

5.2 Intellectual Property Rights (IPR)

Careful consideration has been given to IPR in the preparation of this proposal.

Aspects for which IPR is not expected to be an issue.

The results of the specification and installation phases, the development of any commercial arrangements and the wider carbon benefits and the roll out requirements and assessment of system wide cost and benefits from doing so are not expected to result in or require access to protected IPR.

Electricity Network Innovation Competition Full Submission Pro-forma

Knowledge dissemination continued

Specific Background IPR

The equipment manufacturers associated with the design and construction of the mobile bay components will utilise and modify existing technology for which the IPR is background, for example most aspects of transformer, switchgear and Protection and Control design will have established IP and will be protected by those who own it.

Foreground IPR.

Two aspects of the project are expected to generate relevant foreground IPR:

Where new design and development of MSB equipment is necessary we anticipate that the solution developer will wish to fund this themselves in order to protect any IPR associated with it.

The new specifications and procedures necessary to implement MSBs into the National Grid Transmission system will be relevant foreground IPR. All other GB Network Licensees will have the automatic right to use this IPR for use within their network royalty-free.

Section 6: Project Readiness

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

Requested level of protection against Direct Benefits that they wish to apply for (%):
0%

The following additional information is appended in support of this section:

Appendix 1	Cost Spreadsheet
Appendix 2	Project Programme
Appendix 3	Risk Management and Mitigation Plan
Appendix 4	Contingency Plan
Appendix 5	Project organogram
Appendix 7	List of Global Mobile Substation Projects
Appendix 9	Steering Committee Terms of Reference

6.1 Technology Readiness

The project feasibility has carried out an initial assessment of the current status of technology and applications. Although there is no application at 400kV, we have considered the range of similar projects and examples at lower voltages to establish the feasibility of the concept. Appendix 8 provides a list of these projects.

These projects demonstrate equipment with a technology readiness level (TRL) of 7-9 which ranges from prototype examples to what is now an 'off the shelf' solution at much lower voltages e.g. 11kV. The technology and equipment being used in the MSB project is at a (TRL) of 4-6, i.e. still in development and testing in order to make it rapidly deployable. The new installation and commissioning procedures are at a similar TRL of 5-6 as the concept is considered possible but not implemented or demonstrated yet. The aim at the end of the project will be to have the 400kV MSB up to TRL 8 (actual technology completed and qualified through test and demonstration).

6.2 Resource Readiness

A substantial amount of the project resource will be from National Grid personnel. Key personnel, such as the project manager and substation equipment lead engineers have been identified and are provisionally allocated to be available for this project.

Three schemes in National Grid's construction/maintenance programme for the period 2014 – 2018 have been identified as candidates to host the demonstration project. These projects are fully resourced (design and construction resources) for the business as usual approach and these resources on the chosen site will be available for the MSB project.

The Carbon Trust has identified resources that are already supporting this project and will be available for the duration of the programme.

The other main partner is yet to be selected. A procurement event is currently underway to select the solution provide. This process is planned to be completed by the end of December 2013 with contract award planned for early 2014.

Project Readiness continued

6.3 Programme

The programme is organised into 5 phases. Each phase is triggered by a specific milestone and has its own deliverables and success criteria so that the project can be monitored and governed to ensure demonstrable value for the customer.

If approval is given by Ofgem in Nov 2013, activity will commence so that manufacturer commitments can be made on the 1st April 2014. This will consist of confirming partnerships, procurement activity, signing contracts, confirming relevant outages and forming working groups to complete the various work packages. More detail about each of these work packages is presented in section 2.3 Project Description.

- MSB design & development (April 2014 – March 2015)
- Mobile substation bay manufacture & testing (November 2014 - March 2016)
- 1st Deployment (September 2015 – December 2016)
- Redeployment (January 2017 – December 2017)
- Project review, final report and close out (October 2017 – June 2018)

Knowledge dissemination will occur throughout the programme.

6.4 Project Management / Control

A designated National Grid project manager has been appointed with direct control of the project programme. Control of the project programme and deliverables will be managed by:

- Weekly by the project manager through project team meetings and via work package managers;
- Quarterly project steering committee meetings comprising National Grid and project partners (with powers ;
- Semi-annual project reports to National Grid's internal Project Management Group;
- Annual updates to Ofgem and at the NIC conference.

National Grid projects are required to follow international accounting guidelines as well as internal project management procedures which require the project to be reviewed at the appropriate governance level if any of the key delivery parameters – time, cost and scope – is anticipated to be exceeded. An annual financial audit of the project independent of the MSB project delivery team will be carried out to ensure the spend remains in line with the project plan.

Monitoring and verification of all aspects of the project throughout delivery will take place via National Grid's formal Investment Process. The process begins by establishing a needs case for an investment (stage 4.1). Stage 4.2 considers any number of solutions that are able to meet the needs case set out in stage 4.1 in order to select the best option based on a number of assessment criteria. At stage 4.3 the selected option is developed in detail.

Project Readiness continued

Stages 4.4 and 4.5 are the implementation and closure stages.

Between all stages there are "Gates" where a select party are presented with the information gathered during each of the stages. If the party are not happy with any aspects of the presentation they may chose to ask members of the project team, or in the worst case, suspend the project.

6.5 Project Risk Management

The project incorporates a number of innovative new elements ranging from new technology to new procedures. Consequently, there is a degree of uncertainty and contingency required to ensure the project is successful.

Evidence of how the costs and benefits have been estimated.

National Grid delivers many schemes. Costs estimates are based on typical scheme costs held in a database of past project information. The innovative elements have been estimated through discussions with manufacturers and historical experience around other innovation based projects. The direct benefit costs are based on the numbers from similar types of schemes involving transformer replacements or new installations. The accelerated installation and removal is estimated around the resource on site.

To manage the uncertainty around new technology, a contingency of 50% has been applied to the equipment costs at this stage. This value will come down as the level of risk and uncertainty reduces.

There will also be more resource required during the installation and commissioning phases to help with both unexpected events and to provide advice and record learning.

Minimising the possibility of cost overruns or shortfalls in Direct Benefits

The project risk register, Appendix 3, outlines the key risks that relate to the project and methods to mitigate these risks. More detailed Risk Reviews will be carried out during the detailed design stages of the project. These will be assessed by all members of the project team, as well as a specialist external consultancy. This will enable the team to identify the major risks that could result in shortfalls in funding, time and scope.

There will be a Project Steering committee which will meet regularly to discuss all aspects of the project including finance and will provide a mechanism and governance process to manage any potential shortfalls accordingly.

There are a number of risks associated with both the technology and the delivery of this project. Appendix 3 includes risk management and mitigation options. The technology related risks which underpin the need for this innovative work and why it is not 'business as usual' are outlined in Section 3 Project Business Case, subsection 5.

Project Readiness continued

Verification of information included in the proposal

All information provided in this proposal has passed through a formal governance procedure by which technical aspects have been approved by the Electricity Transmission Asset Management technical governance panel. A senior management review of all information included in this proposal has taken place prior to submission.

How the Project plan would still deliver learning in the event that the take up of low carbon technologies and renewable energy in the Trial area is lower than anticipated in the Full Submission?

National Grid is neutral to the type of generation which connects to the network. The principal behind the MSB is equally valid for the connection of non low carbon technologies and will still be beneficial in reducing the cost of several types of maintenance and replacement activities. There are a range of opportunities where the mobile technology could be used.

The processes in place to identify circumstances where the most appropriate course of action will be to suspend the Project, pending permission from Ofgem that it can be halted.

A steering body will be established to manage project governance, The Draft terms of Reference for which are included Appendix 10. The project planning includes key stage gates which are decision points at which the continued technical and financial viability of the project will be reviewed. The steering group will be responsible for formally reviewing the project on a 6-monthly basis as a minimum.

Contingency Planning

Appendix 4 (Contingency Plan) shows the three circumstances identified by the project team where it may be appropriate to change, delay or temporarily suspend the project. The three circumstances are as follows:

- Project Partner cannot build transformer with sufficient MVA capacity to support trial scheme.
- Project Partner cannot build transformer light enough to justify continuing.
- Trial site Scheme Needs Case changes and the expected work is no longer necessary.

In each of these circumstances it is concluded that the worst possible outcome is a delay to the project and a change in scope. In each case Ofgem would be informed if such a circumstance were to be encountered.

There are a number of project related issues that will need to be managed to assure a satisfactory outcome and demonstrate that the customers are getting good value for money;

- The MSB will be initially a 'one off' design, so the development and manufacturing costs

Project Readiness continued

will be higher than current 'off the shelf' or bulk purchase prices (Figure 3.1 section 3). By its very nature there will be a limited manufacturing volume, so costs and design will be relatively bespoke. The value will come from the re-usability of the MSB offsetting the need for permanent solutions.

- The selection of partner and suppliers has a significant bearing on the delivery of the project both in terms of likelihood of success and value for money. The project is carrying out a selection process using the same procurement model utilised for all other business activity.

Key technology delivery risks will centre around:

- Delays in manufacturing and equipment failing critical tests – The project will aim to initiate manufacturing as early as possible to give suppliers the maximum available time. This can be a major issue if the failure is internal to the transformer. Its design and development will aim to choose solutions which minimise the likelihood of this problem arising. It will be still possible to install just the switchgear bay to prove the concept of rapid and temporary connection to the 400kV busbars. The transformer can than be installed later or as part of the redeployment.
- Exceeding transport design margins. This is one of the key points of innovation, so there will be design margin and emphasis applied to the significance of this issue.
- There is a small risk that site preparation is either insufficient or delayed. The project will work closely with the supplier and site to ensure adequate provisions are made.

Electricity Network Innovation Competition Full Submission Pro-forma

Section 7: Regulatory issues

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

7.1 Relevant Regulatory factors

The project is not seeking any derogations for the duration of the demonstration. The MSB is not replacing or modifying any equipment so should not result in deterioration in performance or reliability. The application of Mobile Substation Bays should not impact negatively on any of the regulatory arrangements.

There is always the potential for an equipment failure which could result in Energy Not Supplied (ENS) or release of SF_6 which could impact on regulatory targets, however the likelihood is no different to that of the business as usual option to install a permanent solution.

Section 8: Customer impacts

8.1 Extent of Impact

The MSB project will largely be carried out on National Grid property and there should be no more impact on customers for the duration of the project than would be experienced under business as usual.

That said, the purpose of the project is to develop and demonstrate how new temporary network capacity can be made available for National Grid customers.

8.2 Customers

This section describes the likely interaction with customers during and after the trial, and those that may be impacted by the roll out of MSBs related applications.

National Grid's direct customers

Customers in the context of this project are those that are directly connected to the Electricity Transmission System, and so limited to connections for power transfers typically more than 100MW. These include generators, such as large wind farms, fossil-fuelled and nuclear power stations, large industrial demands such as steelworks, chemical processing plants and the electricity distribution networks.

Indirect stakeholders

A secondary group will also include those individuals or businesses that may be affected by any related traffic movements or live close to the substation and maybe subject to environmental factors, such as audible noise or, in the event of a fault fire, smoke.

8.3 Managing the quality of service

The objective of introducing the MSB technology is to provide new tools for the network, and provide Transmission customers, with a better, or at least equivalent, quality of service for a lower cost and with greater expediency than is currently possible. In order to achieve this objective, it will be necessary to amend some of the working practices that relate to the installation, commissioning and use of assets connected to the transmission system; as well as disconnection and removal. It is possible that some of NGET's customers could be affected during the MSB installation and commissioning, however this would be no different to existing practice. Throughout the project, National Grid will continue to meet the conditions of the Security and Quality Supply Standard which is part of its transmission licence. If derogation from this standard is required for a particular site and for a limited period of time, an application would be made through the normal process.

The extent to which the MSB project will impact on a customer (for instance a DNO) will depend on the ownership boundary of the 132kV part of the demonstration substation, which will typically be either the busbar disconnectors of the customer's connection, in a substation owned by National Grid, or the busbar disconnectors of an SGT bay in a substation owned by a third party.

Customer impacts continued

The potential impacts on customers can be grouped into issues around planning and operation:

- Preparing the customer's assets for a connection with an MSB.
- Connecting the customer's assets with an MSB.
- Operating the MSB while connected to a customer's assets.
- Disconnecting the MSB from the customer's assets.

In the case of a 132kV substation owned by National Grid, the impact on the customer around planning and connecting an MSB would be negligible. However, in other cases, where the MSB would need to connect to the customer's (e.g. the DNO's) busbars, either in the existing SGT bays or elsewhere, the customer would be impacted.

In these cases, the design of that connection and the preceding preparation work would need to be agreed by National Grid and the affected customer. While these types of activities are normal for both parties, the particulars of the MSB and its temporary nature will require attention. The issues that could be expected to arise while planning the installation and connection of the MSB are likely to include the:

- Methodology for installing and connecting the equipment to the substation.
- Ancillary assets (cables, post insulators, busbars, etc.).
- Protection and control systems.
- Commissioning procedure.

Once the MSB is installed, the customer should not be affected in any way, given that the MSB together with the existing permanent plant will provide sufficient capacity to maintain security of supply. However, in a limited number of scenarios, a fault could prevent the MSB from providing the capacity for which it was intended (however this is no different to the present situation). An example would be the case of a busbar fault on the busbar to which the MSB is connected.

The exception is that the MSB will only have the functionality to connect to one busbar (three phase) at a time, contrary to the typical design of permanently installed assets, which connect to main and reserve busbars with the ability to transfer between them in the case of a busbar fault. It should be noted that the frequency of this type of fault is very low, with about 0.01 occurring per year across 330 substations (none occurred in 2012).

Section 9: Successful Delivery Reward Criteria

Introduction

This section identifies 8 project success criteria and evidence which will be provided to demonstrate success. These are linked to, and highlighted in, the project programme in Appendix 1 and form the basis of project milestones and financial stage gates.

9.1 Evaluation and Selection of Preferred Solution Provider

Criteria

- Declare an assessment methodology.
- OEM initial proposals are submitted to the National Grid Project Team for Evaluation.
- National Grid select preferred solution for further design and prototype build.
- Contract placement.

Evidence

- Procurement process.
- Regular progress meetings to be held between National Grid and OEM design teams, minutes of the meetings held to be available for OFGEM, if requested. OEM initial designs to be submitted to National Grid by Dec 2013. Announcement to be made on the National Grid MSB Twitter/Facebook accounts that OEM proposals have been received and are going to be undergoing evaluation. National Grid announces preferred solution and justification for its decision including its selection criteria by the end of April 2014. Overview of selection process and outcome to be provided in the next six monthly project report. Announcement to be made on the National Grid MSB Twitter/Facebook accounts that OEM proposals have been evaluated and the preferred supplier for the prototype build and trial has been decided. A summary of the initial designs and the specification will be published on the National Grid MSB Innovation Website.
- Signed contracts April 2014. Announcement to be made on the National Grid MSB Twitter/Facebook accounts that OEM contracts have been signed.

9.2 MSB Design & Specification

Criteria

- Functional MSB Specification prepared by National Grid and submitted to the OEMs.
- Feasibility, overview and design guidance to support the initial deployment and subsequent redeployment.

Evidence

- MSB Functional Specification prepared and issued to the OEMs by the end of Jul 2014. A summary of the functional design specification will be published on the National Grid

Successful Delivery Reward Criteria continued

MSB Innovation Website. A copy of the full specification can be provided to OFGEM and other TOs at the same time, if requested. Announcement to be made on the National Grid MSB Twitter/Facebook accounts that the Functional Specification has been submitted to OEMs.

- An overview video of the proposed design, and an introduction on how it works, will be published on the National Grid You Tube Channel by April 2015. Link of the actual video to be placed on National Grid MSB Innovation Website as well as the Twitter/Facebook pages.

9.3 Detailed Design, Manufacture & Testing

Criteria

- Detailed design of the MSB commences.
- Manufacturing of the MSB components.
- Assembly of the MSB and testing.

Evidence

- Agreement reached with all relevant parties within National Grid (Electricity Network Control Centre, Site Operations, Fleet Management and MSB Project Team) and the successful OEM as to which site will be used for the MSB 1st deployment by Jul 2014. All available detailed drawings and specifications of the site to be shared with the successful OEM. Trial site details will be published on the National Grid MSB Innovation Website. Announcement to be made on the National Grid MSB Twitter/Facebook accounts and Innovation Website that trial site has been decided.
- Monthly progress meetings to be held between National Grid and OEM design and manufacturing teams, minutes of the meetings held to be available for OFGEM, if requested. Factory testing programme to be agreed with OEM. Announcement to be made on the National Grid MSB Twitter/Facebook accounts that OEM prototype is being produced and will undergo evaluation.
- By April 2016 the factory testing including agreed programme to be completed. Announcement whether testing has been successful or not to be published on the National Grid MSB Innovation Website. Outcome of Factory testing to be included as part of the next 6 monthly project report.

9.4 Development of MSB Safety & Operational procedures

Criteria

- Safety procedures prepared and approved by National Grid.
- Operational procedures developed and agreed with Electricity Transmission System Operator.

Successful Delivery Reward Criteria continued

Evidence

- MSB safety procedures prepared with cross company working groups. Approved and shared with the OEMs and any impacted Customer by the end of Jun 2015. A summary of the procedures will be published on the National Grid MSB Innovation Website. A full copy of the procedures can be provided to OFGEM, if requested. Announcement to be made on the National Grid MSB Twitter/Facebook accounts that new safety procedures have been approved.
- MSB operational procedures prepared with cross company working groups. Approved and shared with the System Operator and any impacted Customer by the end of Jun 2015. A summary of the procedures will be published on the National Grid MSB Innovation Website. A copy of the procedures can be provided to OFGEM, if requested.

9.5 First deployment of the MSB on the Transmission System (site A)

Criteria

- Confirm site access, bay location and outages for MSB installation (Site A).
- Assemble project delivery team for installation and 1st deployment period.
- Pre-outage site preparation for MSB (site A).
- Installation & commissioning of MSB (site A).

Evidence

- Agree the specific location and work programme for the MSB to ensure the resource and site access from April 2016 for the preparation, installation and performance evaluation. System Outage request form to be submitted for May 2016 (15 days) to allow installation of the MSB and performance trials (Site A).
- By April 2015 establish the project delivery team to ensure that the MSB can be redeployed in an efficient and compliant manner (including CDM regulations) to site B.
- MSB method statements prepared and issued to all parties by the end of March 2016. A summary of the procedures and safety rules will be published on the National Grid MSB Innovation Website. A full copy of the can be provided to OFGEM at the same time as the OEMs, if requested.
- From May 2016 to September 2016 the MSB technology will be installed at site A. Commissioning planned for June 2016. Announcement to be made on National Grid MSB Innovation Website as well as the Twitter/Facebook pages that installation has been completed.

9.6 First Redeployment of an MSB (to site B).

Criteria

- Pre outage site preparation of bay (Site B).
- Decommission MSB and prepare for transport to new bay (Site A).
- Transport and inspection of MSB.
- Install & commission MSB at Site B.

Evidence

- Agree the specific location and work programme for the MSB redeployment (site B) to ensure the resource and site access from March 2017 for the preparation, installation and performance evaluation. System Outage request form to be submitted for May 2017 (15 days) to allow installation of the MSB and performance trials at site B.
- Agree work programme for decommissioning of the MSB at site A to ensure the resource and site access from Feb 2017 for the preparation and decommissioning and site clear up. System Outage request form to be submitted for Mar 2017 (15 days) to allow for decommissioning of the MSB at site A. Method statements prepared and issued to all parties by the end of Dec 2016.
- Ensure transport logistics are arranged to collect and deliver the MSB from site and deliver to base April 2017. The MSB will be inspected and any modifications/repairs facilitated during this phase.
- From May 2017 the MSB technology will be installed at site B. Commissioning planned for Jun 2017. Announcement to be made on National Grid MSB Innovation Website as well as the Twitter/Facebook pages that installation has been completed.

9.7 Alternative commercial arrangements for MSBs.

Criteria

- Identify market and appetite for temporary capacity in utility business models.
- Establish viability of different ownership arrangements for MSBs.
- Investigate commercial mechanisms to deliver MSB functionality.
- Evaluation of commercial arrangements for provision of temporary capacity.

Evidence

- Exploratory meetings to be held with other TOs, OEMs and other service providers to investigate the feasibility of different delivery models, minutes of the meetings held to be available for OFGEM, if requested.
- Feasibility study to be carried out in consultation with other TOs, OEMs and other service

providers to investigate the feasibility of different delivery models, storage and service levels Sept 2017. Minutes of the meetings held to be available for OFGEM, if requested. A report of the study findings will be published on the National Grid MSB Innovation Website.

9.8 Project learning, Knowledge Dissemination and Project Close Out.

Criteria

- Review the learning and update specifications & procedures.
- Ensure that knowledge is disseminated from the trial.
- Close the MSB project out.

Evidence

- In November 2017 the conclusions and benefits of the MSB programme will be independently verified. An estimate of the carbon savings that will potentially be achieved through utilising MSBs will be reviewed by an independent recognised organisation, the Carbon Trust. The potential savings to customers will be re-evaluated based on the outcomes of the programme. National Grid will also conduct a final assessment on how widely MSB technology can be rolled out across the various capital and delivery programmes.
- By December 2017 a technical paper will be prepared which will be submitted for publishing in at least two of the following institution journals – Institute of Engineering and Technology (IET), CIGRE or IEEE. In December 2016 a summary paper of the findings will be prepared and published on the National Grid MSB Innovation Website; a link to the report will be published on the MSB Facebook/Twitter pages. The outcomes of the Project will also be shared with the National Grid Electricity Transmission Customers at the next available forum following its completion. Upon successful completion of MSB project it will be put forward for inclusion in the National Grid Shareholder's Annual General Meeting as well as National Grid's Annual Performance Report. The Project Team will produce an overview video presentation on the MSB project and its benefits, the Video will be published on the National Grid You Tube channel. Link of the actual video be placed on National Grid MSB Innovation Website as well as the Twitter/Facebook pages. If successful the National Grid Specification will be updated to ensure that this technology forms becomes a normal business design option.
- By April 2018 the final six monthly report will be produced providing an overview of the project in its entirety, it successes and delivery against its initial goals. The project finances will be finalised by June 2018. The Project Team will present the findings from the MSB project at the next available NIC Annual Conference.

Electricity Network Innovation Competition Full Submission Pro-forma

Section 10: List of Appendices

This submission is supported by the following appendixes:

Appendix	Title	Description
1	Full Submission Cost Spreadsheet	Provides a breakdown of development and delivery cost and spend phasing of the MSB project
2	MSB Project Programme	Detailed project programme including contingency
3	MSB Project Risk Management Plan	Risks associated with MSB delivery and mitigation measures in place to prevent them being realised.
4	MSB Project Contingency Plan	Major risk items and contingency measures in the event they are realised.
5	Organogram	Project structure illustrating governance, management and communication accountabilities.
6	Letters of support	
7	Review of Global Mobile Substation Projects	Provides information about examples of mobile substation projects from a number of countries together with their voltage levels
8	Substation Site Pictures	Examples and images of extra high voltage substation equipment
9	Steering Committee Terms of Reference	Draft terms of reference for the MSB project steering committee
10	Base and Method Cost Details	Explanation of the assumptions used in estimating cost and benefits
11	Application examples, benefit estimation and technology readiness	Illustration of how MSB's will be used, review of MSB potential in schemes completed in the last 10 years, forecasts of future MSB deployments over the next 10 years and technology maturity,
Addendum	Summary of changes compared to original submission	

Appendix 1
Full Submission Cost Spreadsheet

Appendix 1 has been removed as the material is commercially sensitive.

Electricity Network Innovation Competition Full Submission Appendices

Appendix 2
Project Programme

Appendix 3
Project Risk Register Risk Management and Mitigation Plan

Cause 'As a result of….'	Risk Description 'There is a risk/opportunity that…..'	Consequence 'This would lead to a…'	Likeli-hood (%)	Cost impact (£k)	Time impact (days delay to ACL)	Action / Mitigation
Unsuccessful Procurement Event	Cannot secure appropriate OEM partnership	Delays to project start and increased cost	5%	[redacted]	150	Engage OEM early to ensure that enough interest is generated in the project
Problems during the procurement process	Delays in manufacturing and test completion	Delays in project completion and possible increase in cost	5%	[redacted]	40	Allow enough time to ensure that any potential delays do not have an impact on the project
Existing FAT and Type Registration Process	Equipment fails FAT or type registration	Delays in project completion or requirement to stop project	10%	[redacted]	60	Engage FAT and Type Registration teams throughout the procurement process
New functional and technical specifications produced	Equipment design does not meet specifications required in terms of size or rating	Delays in project and increased costs	5%	[redacted]	100	Monitor Procurement process to ensure deliverables are set out and met
Reuse of connection points	There may be increased risk of faults at connection points	Repair costs and delay to installation. If oil spills occur, Possible environmental clear	5%	[redacted]	5	Design for multiple connections and many cycles of use. Follow working procedure.

		up costs and impacts				
Filling 3 phase transformer unit on site if it is too heavy to transport with oil	Oil leaks during filling	Repair costs and delay to installation. Possible environmental clear up costs and impacts	5%	[redacted]	5	Follow working procedures and modify guidance notes accordingly
The project not delivering required outputs	Redeployment is not favourable over a standard substation solution	Delay in redeployment	20%	[redacted]	300	Consider a number of circumstances with varied output requirements.
Regular reinstallation and movement of parts	General wear and tear	Increased maintenance costs and potential delays when redeploying	20%	[redacted]	10	Design fit for purpose. Procedures designed in order to minimise risk
P&C incorrectly designed	P&C may fail	delay to the programmes and increased cost of commissioning and replacing faulty panels and parts	5%	[redacted]	15	Safety by design.

Faults in deployment or design of trailers containing mobile units	Connections could fail, moving parts	Increased maintenance costs and potential delays when redeploying	30%	[redacted]	10	Fit for purpose, take in to account ground conditions from an early stage potentially conducting GPR surveys in advance.
Adverse weather conditions	Lightning strikes, flooding, varying ground conditions	Damaged equipment causing increased cost and delayed programme	10%	[redacted]	10	Ensure suitable protection is installed in line with the relevant guidance notes
Poor Site Security and Access	Damage to equipment on delivery	Repair costs and delay to the programme	2%	[redacted]	10	Check routing and security at each site where the Mobile units are to be installed
Low temperature	Damage to connections causing leakages	Repair costs and delay to the programme	5%	[redacted]	10	Design fit for purpose. Procedures designed in order to minimise risk
Insufficient oil containment	If a leak occurs the containment breaks or is not big enough to contain the leakage	Environmental clean up costs	5%	[redacted]	5	Use correct equipment. Modify guidance documentation accordingly
Nomenclature is not suitable (HVSCC)	No agreement could me made between involved parties regarding nomenclature for	Delay to the programme	5%	[redacted]	50	Discuss with all parties involved well in advance and modify guidance notes accordingly

	temporary structures					
Lack of sufficient drainage due to temporary deployment of the Mobile Units	Flooding cause failure of or damage to the mobile bay	Increased cost for repair	10%	[redacted]	30	Conduct drainage surveys prior to deployment at all relevant sites
Asset registration process not suitable	No way of monitoring equipment time in use could result in maintenance issues	Delay to the programme	10%	[redacted]	50	Discuss with all parties involved well in advance and modify guidance notes accordingly
Connecting new busbars/conductor to existing AIS Busbars	Rating cannot be matched	Increased engineering and design costs as well as delay to the programme	10%	[redacted]	10	Correct design and design assurance.
New Joints connected to existing busbars	Temperatures are too high in clamps/joints top support the HV connections (Hot Joints)	Increased engineering and design costs as well as delay to the programme	10%	[redacted]	10	Correct design and design assurance.
Cable / Air Terminations	Failure of the cable/air termination points	Supply failure and increased costs	10%	[redacted]	0	Correct design and design assurance. Maintenance and monitoring when live.

A lack of space for connecting to the existing AIS busbars	Safety distances are infringed	Unsafe working conditions are made or project cannot be delayed	20%	[redacted]	30	Site Surveys and assessment prior to installation
There being insufficient space / access to chosen deployment site	Major modifications to site need to be made in order to gain access and set up mobile gear	Delay to programme and increased cost	10%	[redacted]	40	Site Surveys and assessment prior to installation
A no build option becomes favourable	The trial site is no longer suitable	Delays to project	20%	[redacted]	200	Establish a portfolio of sites where implementation of the project would be suitable.
Dimensions of equipment being larger than anticipated	Major modifications to site need to be made in order to gain access and set up mobile gear	Delay to programme and increased cost	10%	[redacted]	40	Detailed design assessment prior to purchasing
A lack of space for manoeuvring trailers on site (turning circles for instance)	Major modifications to site need to be made in order to gain access and set up mobile gear	Delay to programme and increased cost	10%	[redacted]	40	Site Surveys and assessment prior to installation

Equipment too heavy to transport by road and on site roads	Breaking the law, damage to site roads and potentially damaging the equipment	Delay to programme, increased cost and legal fees	10%	[redacted]	30	Ensure highways agency information is understood and road bearing capacities at specific sites are taken into account.
Limited or unsafe access for maintenance	Inability to make repairs without additional procedures being in place	Increased cost and longer off-line	10%	[redacted]	0	Safety by design
Working on Third Party sites	Cannot access easily for maintenance or delivery of Mobile units to site	Delay to programme and increased cost	10%	[redacted]	30	Ensure agreements with Third Parties are made well prior to deployment
Deploying busbars, conductor and/or cables around site	Site access is restricted for maintaining existing equipment	System issues	20%	[redacted]	0	Planning in accordance with relevant guidance notes and site rules
Cable jumping in fault conditions	Cables crash into other equipment causing damage	Increased costs	5%	[redacted]	0	Trefoil cable system or other means of minimising movement under fault conditions
Fault to Mobile or existing equipment	Cannot secure outages due to proximity of new connections	Delays to repairs resulting increased costs	10%	[redacted]	0	Planning in accordance with relevant guidance notes and site rules

Failure to identify relevant Guidance notes and procedures	Conflict during all stages of the process of deployment of the project	Delays to the programme	40%	[redacted]	50	All parties involved from the outset and throughout planning and implementation
Unexpected ground conditions	Civil work and permanent foundations unexpectedly required	Delay to programme and increased cost	30%	[redacted]	30	Ground surveys prior to deployment and agreement over policy relating to temporary works
Insufficient working procedures	Works cannot take place or mistakes are made	Delay to programme and increased cost	30%	[redacted]	40	All parties involved from the outset and throughout planning and implementation
Conflicting information in different guidance notes and procedures	Conflict during all stages of the process of deployment of the project	Delays to the programme	40%	[redacted]	50	All parties involved from the outset and throughout planning and implementation

From the risk register produced above, the main risk areas which impact the critical path are as follows:

1.) New functional and technical specifications developed for the new equipment

At an initial stage, most of the risks lie within this area. If the new specifications are not defined in time or OEMs believe that these are not achievable, then the project will not be able to start in a timely manner. There is also a risk that if the bespoke equipment is complex to manufacture and the market is limited, then OEMs may charge a premium for it.

In order to mitigate this risk, National Grid is already undergoing an exercise to gather market intelligence and understand what solutions are already in use around the world (as explained in Appendix 7). Using these, informed decisions can be made in order to come up with a cost effective achievable design in the right timescales.

2.) Procurement and OEM partner selection events.

While the above mitigate some of the risks associated with the procurement event, a risk still exists that the relevant OEM partnership cannot be secured in time. This will again impact the start date of the project. In order to decrease this risk, OEMs are being engaged early and a PIN (define?) has already been published in order to inform the market of the imminent start of the project and gauge supplier interest.

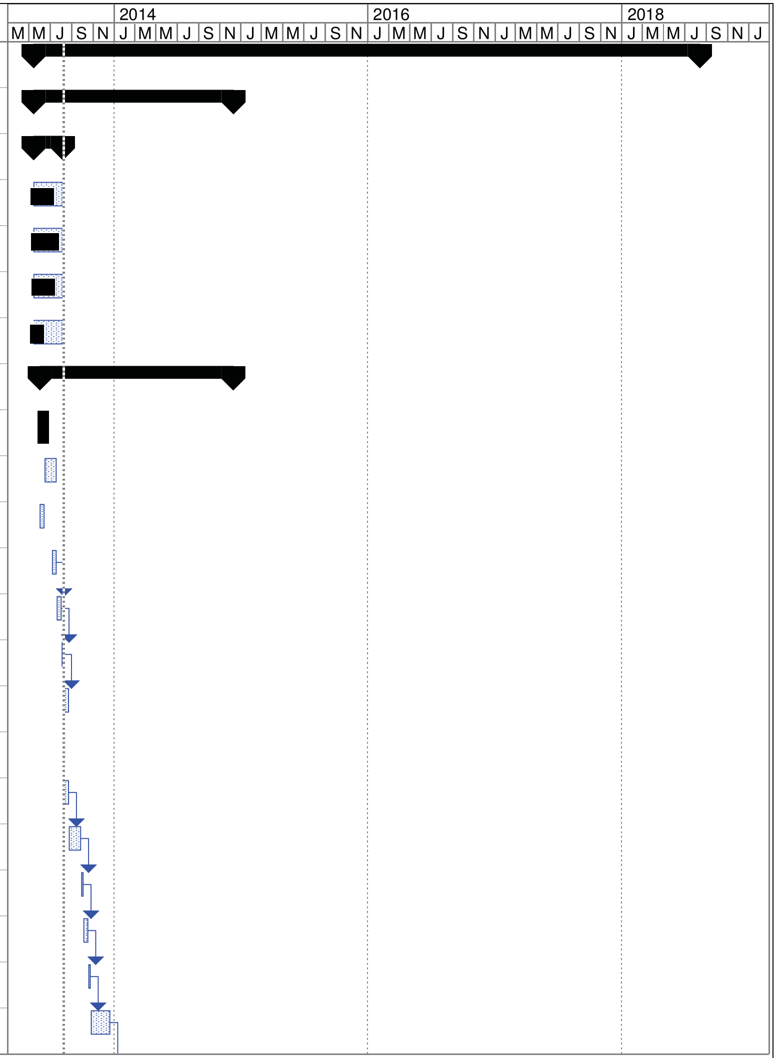
3.) Manufacturing

After this stage, the risks shift to the manufacturing process. As this is new equipment, there is an increased risk that of it not being able to pass its Factory Acceptance Testing (FAT) or getting type registered in the required timescales. This can have significant impact on delivery time of the equipment. This risk will be managed from the start of the project by undergoing a robust procurement process which will allow National Grid to select a reliable OEM. Furthermore, throughout the design and manufacturing process, all relevant parties will be engaged in order to ensure that the equipment can meet its desired performance requirements.

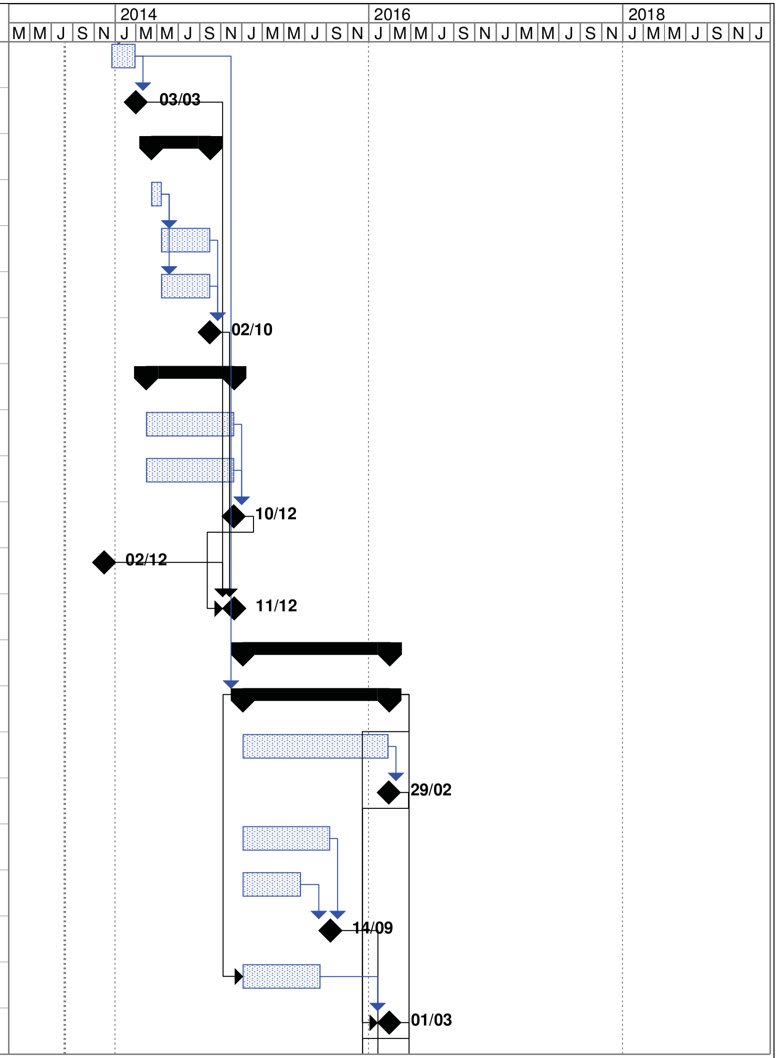
4.) Site deployment

Finally, the major area of risk lies within the deployment. As with any project, the investment has to be targeted at the site which benefits the most from this. There is a risk that the site selection may change as the project progresses. There is also a risk that once a site has been selected, the site conditions (ground, access, space) make it hard for it to accept a mobile solution without requiring any of the works which a permanent solution would. In order to mitigate these risks, a number of sites are being looked at in order to ensure that the site selected has a strong need for the solution and is able to easily accommodate an MSB.

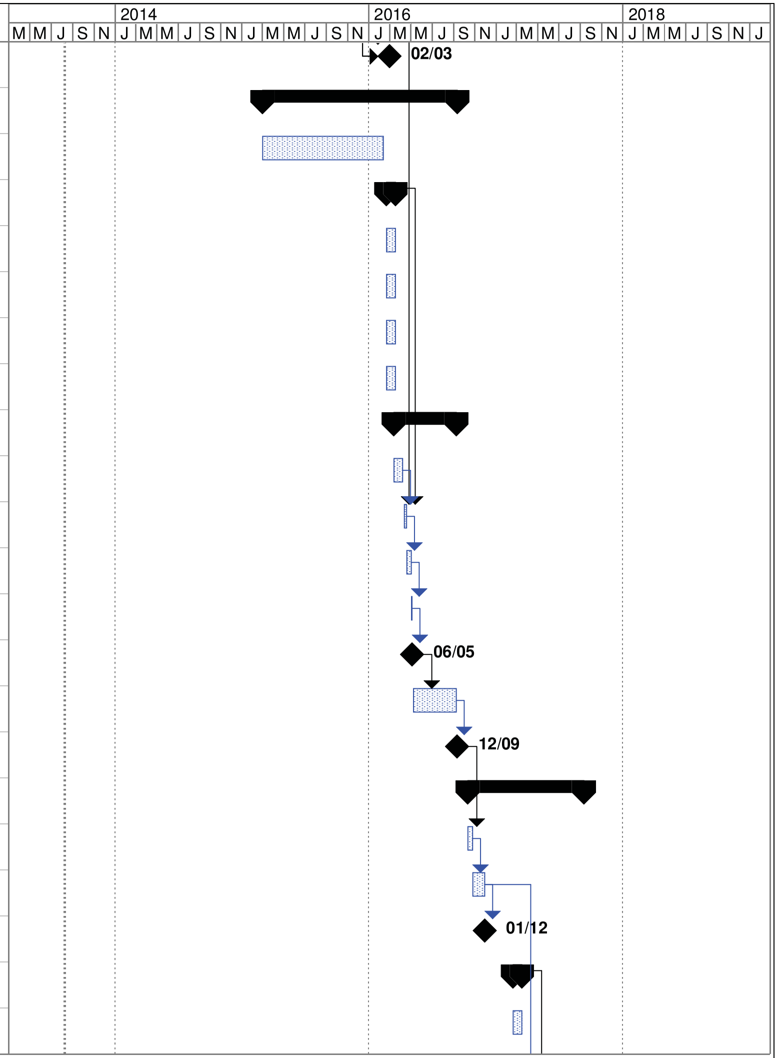
ID	Task Name
1	**Mobile Substation Project**
2	**PHASE 1 - MSB Design and Development**
3	**Identify Deployment Options**
4	Product availability/development needs (supplier engagement)
5	Applicable schemes and detailed CBA
6	Case (desktop) studies for typical applications
7	Initial risk analysis
8	**Procurement**
9	PIN (Periodic Indicative Notice) Issued
10	PIN return Response
11	Establish team
12	PQQ Draft
13	PQQ Issue
14	PQQ response
15	PQQ Evaluation
16	Supplier Day
17	RFP - Draft
18	RFP - Release
19	RFP - Tender Response
20	RFP - Tender Evaluation
21	TQ and rescore
22	Negotiations



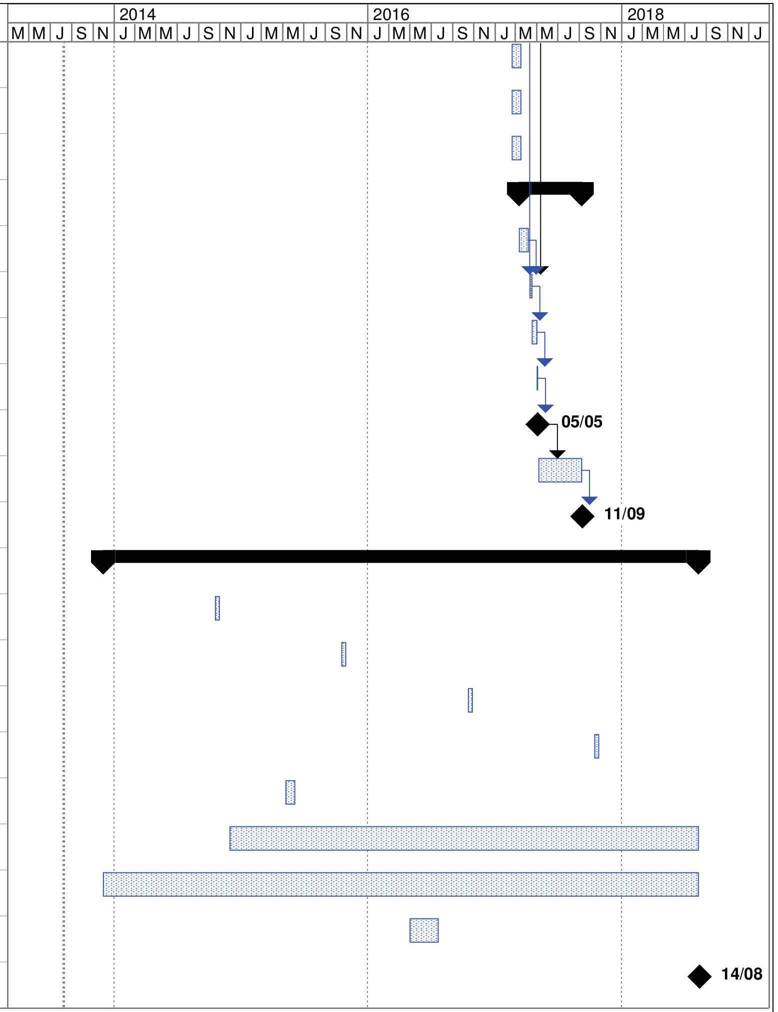
ID	Task Name
23	Contract Award Process
24	Signed Contract With Suppliers
25	**New and Amended Technical Specifications/Policies**
26	Establish Technology Workstreams
27	Functional Spec (SWG, P+C)
28	Functional Spec (Transformer)
29	Specification Approved
30	**New and Amended Safety Rules/Work Procedures**
31	Safety Rules Updated
32	Working Procedures Updated
33	Revised Work Procedures Approved
34	Agreed Deployment Sites (for NIC +4 months)
35	**Stage Gate 1**
36	**PHASE 2 - MSB Manufacture and Testing**
37	**MSB Manufacture**
38	Transformer Manufacture & Testing
39	MSB Transformer Factory Acceptance Testing Successful
40	Switchgear Manufacture & Testing
41	Protection & Control Manufacture & Testing
42	MSB Switchgear Factory Acceptance Testing Successful
43	Type Registration
44	Type Registration Complete



ID	Task Name
45	**Stage Gate 2**
46	**PHASE 3 - First Deployment**
47	Scheme Design
48	**Survey**
49	Route Survey
50	Ground investigations
51	Ecological/Archaeological Surveys
52	Proximity surveys
53	**Delivery Phase**
54	Stage 1: Pre construction and light civil works
55	Stage 2: MSB Delivery
56	Stage 3: Installation
57	Stage 4: Commissioning
58	Commissioned MSB
59	Deployment Period
60	**Stage Gate 3**
61	**PHASE 4 - Redeployment**
62	Decommissioning
63	Inspection
64	Successful Decommission and Inspection
65	**Survey**
66	Route Survey



ID	Task Name
67	Ground investigations
68	Ecological/Archaeological Surveys
69	Proximity surveys
70	**Delivery Phase**
71	Stage 1: Pre construction and light civil works
72	Stage 2: MSB Delivery
73	Stage 3: Installation
74	Stage 4: Commissioning
75	Commissioned MSB
76	Deployment Period
77	**Stage Gate 4**
78	**PHASE 5 - Learning and Dissemination**
79	1st NIC AGM Paper
80	2nd NIC AGM Paper
81	3rd NIC AGM Paper
82	4th NIC AGM Paper
83	Review Commercial Delivery Mechanisms
84	MSB Website Management
85	MSB Social Media Management
86	Roll Out and Implementation Plan
87	**Project Closure**



Electricity Network Innovation Competition Full Submission Appendices

Appendix 4
MSB Project Contingency Plan

Electricity Network Innovation Competition Full Submission Appendices

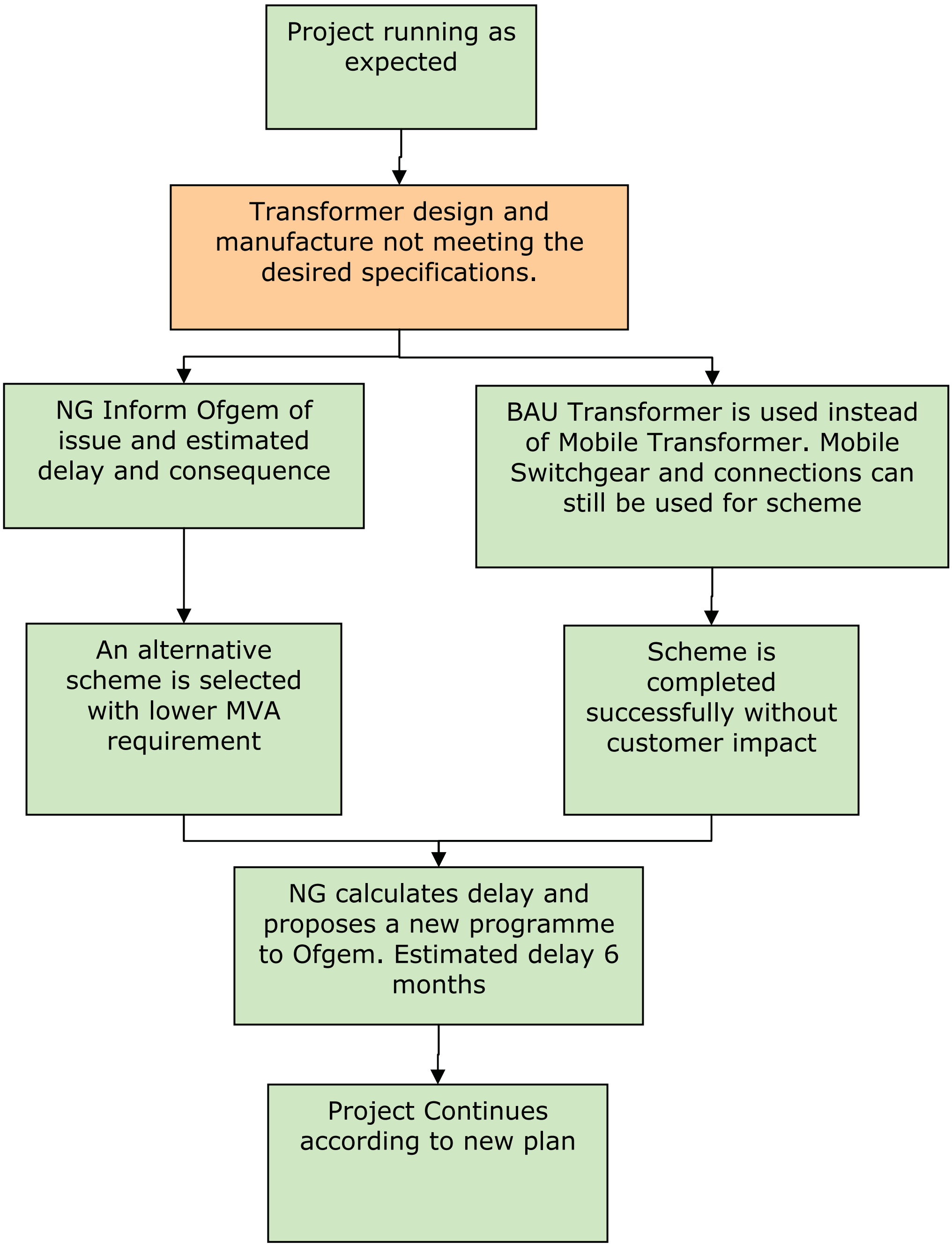
The 4 scenarios where contingency would need to be put in place are:

1. Transformer design and manufacture not meeting the desired specifications.
2. Design and manufacture of self installing system not adequate
3. Change to requirements of the site targeted for deployment
4. Faults on site once equipment is installed

The project board will need to be convened at least once every 3 months and at each milestone to review the progress so far and give their approval for the project to carry on under the original scope. If any of the above risks materialise, then a contingency plan has been developed to deal with them.

Scenario 1

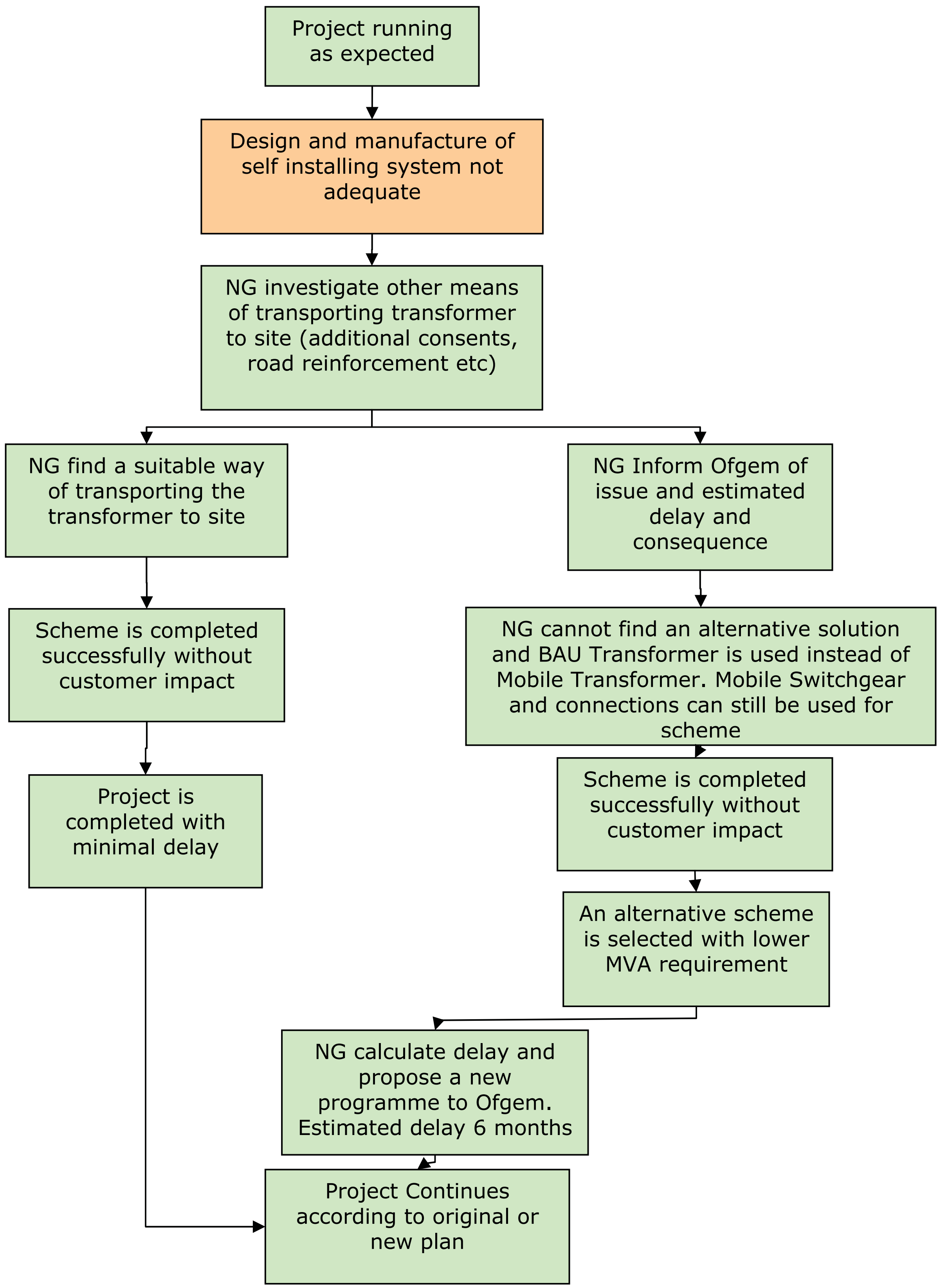
At the end of the transformer design process, if the desired specifications cannot be met, a sensible trade-off between MVA achievable, size and weight of the equipment would need to be reached. A decision would need to be taken on whether any amount of useful capacity could be achieved by a transformer which is small enough to be transported without requiring any special permits. If this is not the case, then discussions will need to be held with the Highways Agency to come up with a sensible design which would require limited permits on pre-agreed routes.



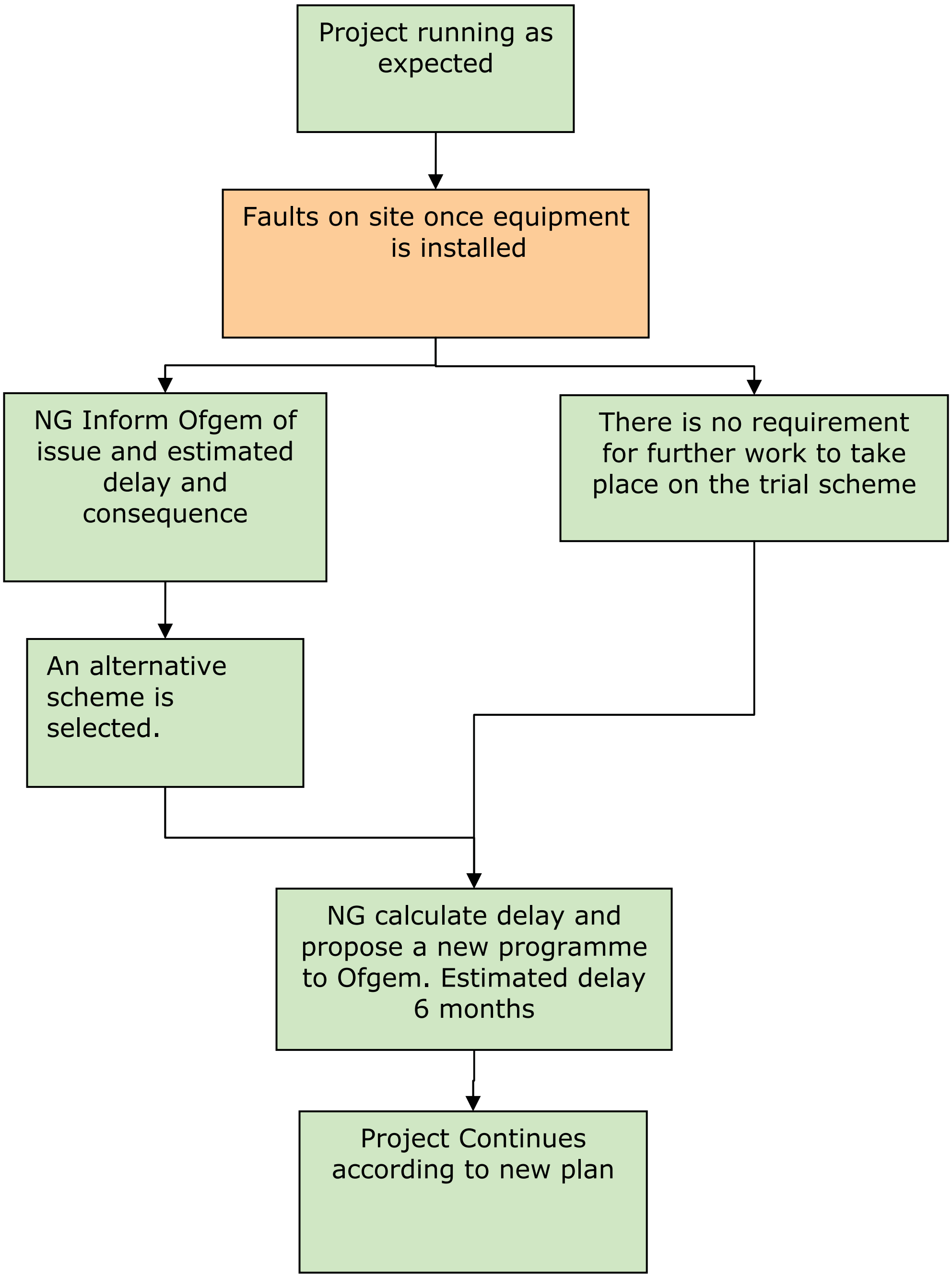
Scenario 2

If the design of the transformer does not include for a platform on which it could be deployed without the use of any further equipment, the use of cranes and other heavy lifting equipment will need to be considered. While the use of additional equipment will not stop the project, it may lead to increased costs, complexity and outage duration. This will be taken into account in the design stages ahead of first deployment.

Electricity Network Innovation Competition Full Submission Appendices

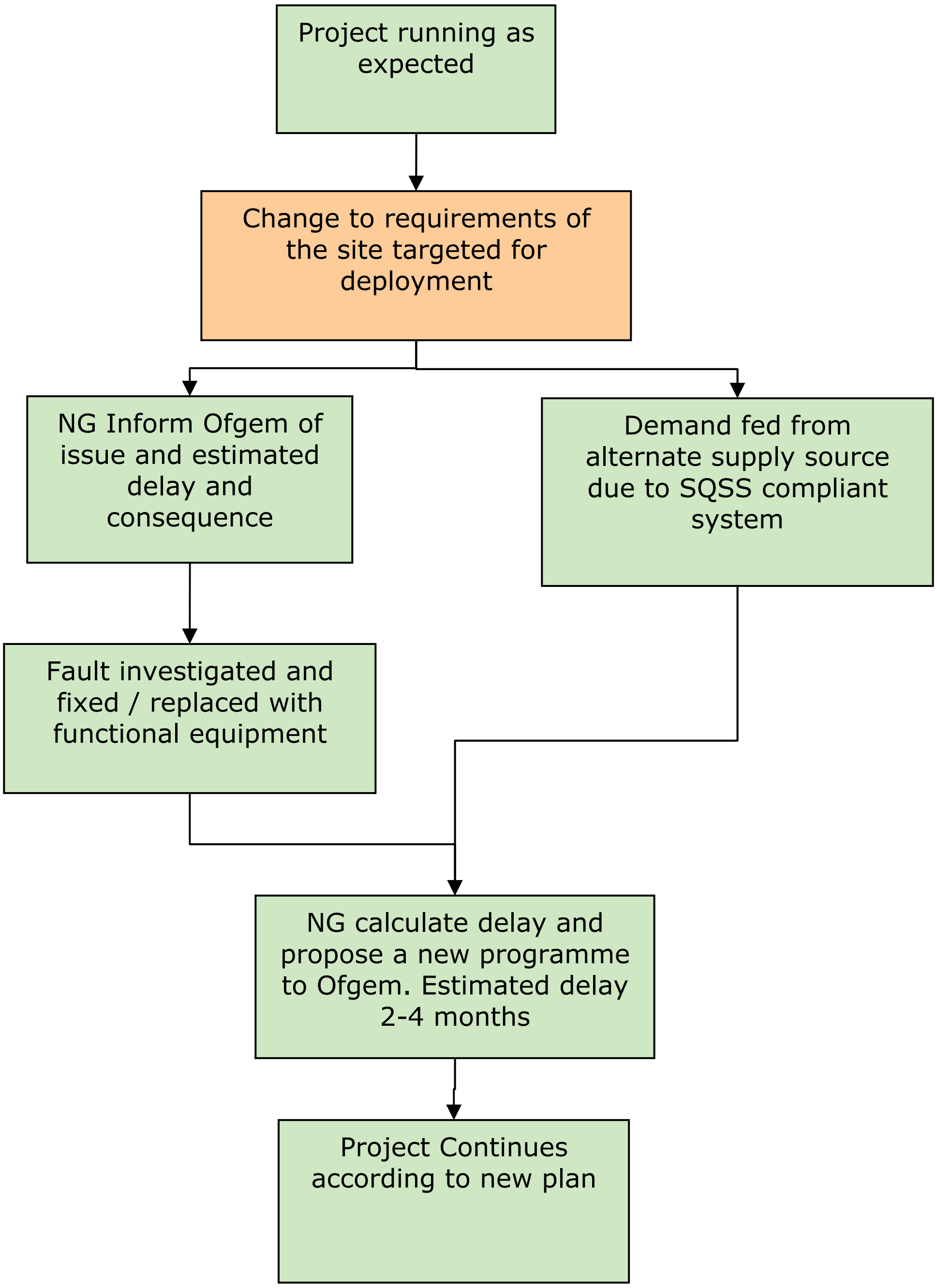


Scenario 3



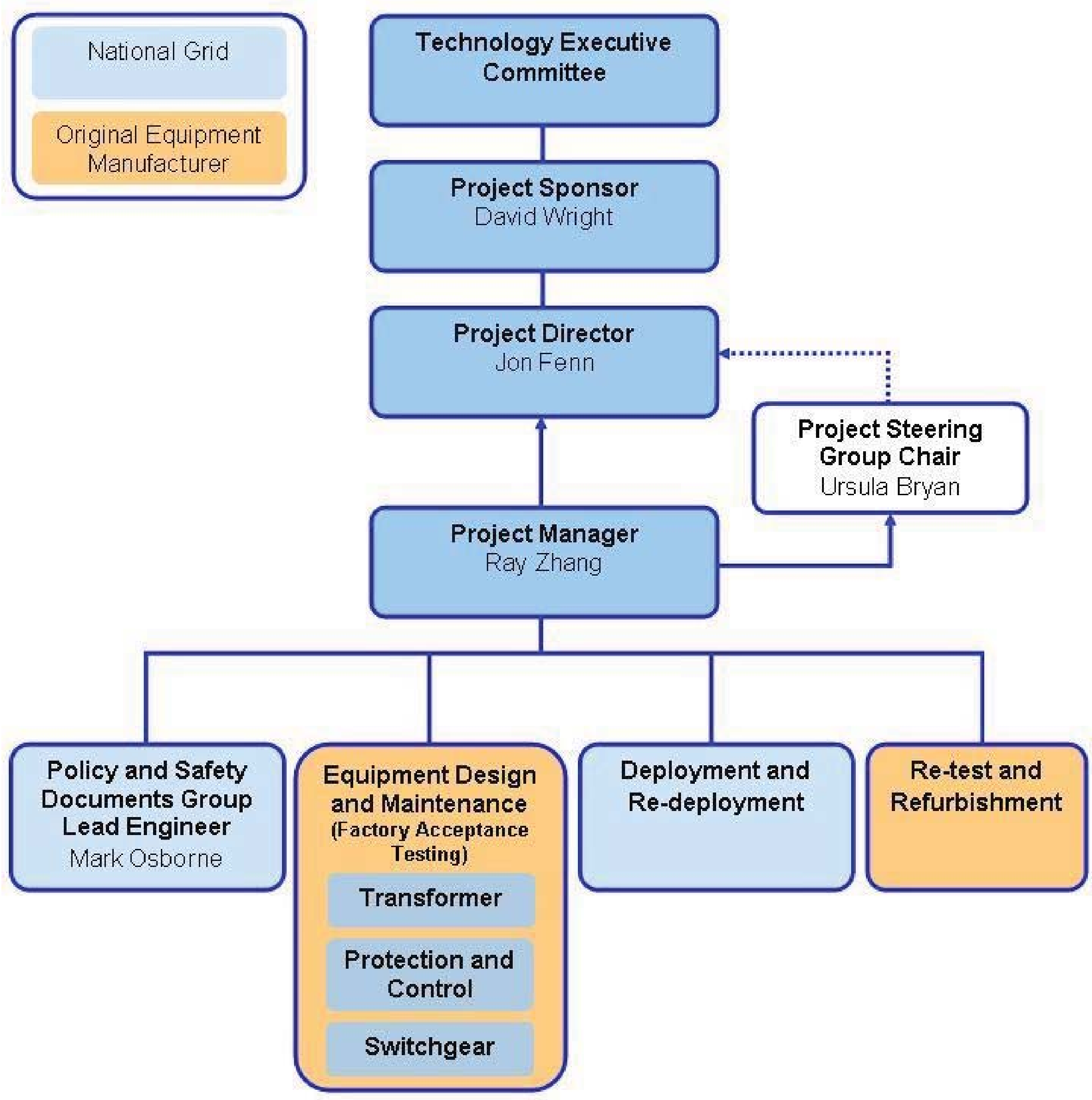
As with any project, the investment has to be targeted at the site which benefits the most from this. If the requirements of the sites selected for deployment change, then a different site may be selected. In order to ensure that this will not halt the project, numerous sites are currently being worked up. Furthermore, the solution will be designed to be as generic as possible in order to ensure that it can be applied to numerous sites.

Scenario 4



If the equipment fails on site after it has been commissioned, then demand may be at risk. As per usual operation requirements under the SQSS, the Electricity Transmission Network will be operated in such a way so that it can cope with the loss of the mobile equipment with limited impact to customers. This can be achieved through demand transfer and bringing other circuits back on the system ahead of the planned dates. The causes of the failure will need to be assessed and if possible, these will be resolved during the downtime until the following deployment.

Appendix 5
MSB Project Organogram


National Grid
Original Equipment Manufacturer
Technology Executive Committee
Project Sponsor
David Wright
Project Director
Jon Fenn
Project Steering Group Chair
Ursula Bryan
Project Manager
Ray Zhang
Policy and Safety Documents Group Lead Engineer
Mark Osborne
Equipment Design and Maintenance
(Factory Acceptance Testing)
Transformer
Protection and Control
Switchgear
Deployment and Re-deployment
Re-test and Refurbishment

Electricity Network Innovation Competition Full Submission Appendices

Appendix 6
MSB Project: Letters of Support

Electricity Network Innovation Competition Full Submission Appendices

Scottish Power Transmission Letter of support

SP ENERGY NETWORKS

To: David Oram
Network Innovation Competition Manager
UK RIIO Delivery, National Grid,
Warwick, England

01-August-2013

Dear David:

Re: National Grid Electricity Transmission plc:
Mobile Substation Bays (MSB)

ScottishPower are please to provide this letter of support for their Mobile Substation Bays (MSB) project.

ScottishPower recognise the value of mobile substations, transformers and switch-bays; these having been employed at distribution network voltages, for the emergency restoration of supplies following plant failure. However we do recognise that the deployment of portable transmission plant presents significantly greater challenge with its increased size and weight and installation issues.

SPT recognise the benefits of MSB project in the delivery of TO capital programmes for both asset replacement and the connection renewable generation connections. The ability to provide temporary transmission switch-bays to facilitate off-line new substation build, may provide significant reductions in outage times and hence potential saving in network constraints. The portability and "plug and play" attributes of the proposed plant design arrangements will assist in the acceleration of new renewable connections.

SPT benefit from a "Spares Club" arrangement with NGET, where significant savings may be realised by the sharing of common network component spares. We look forward to discussing with NGET how the MSB project may become part of the spares holding arrangement where the project benefits may be shared.

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

Yours sincerely

Jim Sutherland

Engineering Director, SP Energy Networks

New Alderston House, Dove Wynd, Strathclyde Business Park, Bellshill ML4 3FF
Telephone 0141 614 0008
www.scottishpower.com

Electricity Network Innovation Competition Full Submission Appendices

Scottish Hydro Electric Transmission Letter of support

Scottish and Southern Energy
Power Distribution

Inveralmond House
200 Dunkeld Road
PERTH
PH1 3AQ

Telephone: 01738 456237
Email: stewart.a.reid@sse.com

David Oram,
Network Innovation Competition Manager,
National Grid Electricity Transmission
National Grid House
Warwick technology park
Gallows Hill
WARWICK
CV34 6DA

Our Reference:
Your Reference:

Date: 6 August 2013

Dear David

Network Innovation Competition – National Grid Electricity Transmission
Mobile Extra High Voltage Substation Bays - 'MSB' - Project.

Scottish Hydro Electric Transmission are pleased to provide a letter of support for National Grid Electricity Transmissions MSB project. Whilst we are not a partner in the project we have a keen interest in the outputs and learning from the project.

At present SHE Transmission only have a limited 400kV network, however, this will increase substantially as our network develops to meet the challenges of an ever increasing volume of renewable generation. The MSB project has the potential to provide us with learning which will help us manage this network in future.

Overall we see MSB as an exciting project which has the potential to improve some of the construction and maintenance activities and ultimately deliver benefits for customers.

Yours faithfully

Stewart Reid
Future Networks Manager

Z:\B - Research & Development_NIC Current Projects\NIC 2013\NGET MSB Project\MSB Letter of Support.doc

Electricity Network Innovation Competition Full Submission Appendices

Carbon Trust letter of support

David Oram
Network Innovation Competition Manager
National Grid
National Grid House
Warwick Technology Park
Warwick, CV34 6DA

3rd July 2013

Dear David,

Re: Network Innovation Competition 2013

Carbon Trust is fully supportive of the projects submitted by National Grid as part of the Network Innovation Competition. We have already provided support to National Grid during the Initial Screening Process for 3 of the projects (MEdiCi, MSB and VECTOR).

If these projects are successful during the full submission, we look forward to on-going support of these projects, particularly in the areas of CO2 impact of each of the projects and dissemination of the outputs of the project to a variety of audiences via a range of methods, including but not limited to site visits, conferences, trade PR, website content and end-consumer factsheets.

If you require further information please do not hesitate to contact me on 020 7832 4610.

Yours sincerely,

Al-Karim Govindji

Al-Karim Govindji
Manager, Innovation
For and on behalf of
THE CARBON TRUST

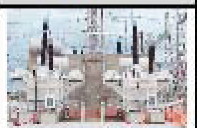
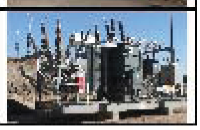
Electricity Network Innovation Competition Full Submission Appendices

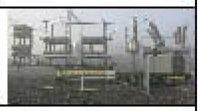
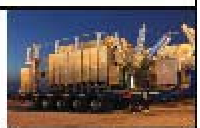
Appendix 7
MSB Project: Review of Global Mobile Substation Projects

Electricity Network Innovation Competition Full Submission Appendices

This is a summary of projects from around the world which have employed elements of mobile or transportable power system equipment. The information has been gathered from our discussions with manufacturers to establish the viability of developments at 400kV. Internet searches, which yield more examples of mobile switchgear, transformers, bays and substations, however we have concentrated on the applications at higher voltages.

There are multiple uses of mobile transformer and switchgear solutions all around the world with many different purposes, sizes, and suppliers. One common theme with all of these projects is that all the mobile substation bays solutions are all at voltages below 300 kV, there are individual components e.g. 400 kV mobile transformer. However, so far a complete, rapidly deployable, mobile bay at 400 kV has not been installed.

Location	Equipment	Voltage	Supplier	Year	Purpose	Image
Spain, REE	Poly-transformer *Rating: 350 3x117*	400 kV, 230, 138kV	ABB	2010	Security contingency. Worlds first 400kV mobile Tx	
Spain	Switchgear	300 kV	Siemens	-----	Substation extension	
United Arab Emirates, ADWEA	Transformer, GIS	245 kV 220/33?	ABB	-----	Mobile GIS & transformer	
Algeria	Transformer	220/60	Siemens	-----	Emergency	
Spain	GIS switchgear	145 kV	Alstom	2009	4 bay mobile substation	
S. Africa	Transformer, switchgear	145 kV	Siemens	-----	Move capacity	

Spain	Switchgear	145 kV	Siemens	-----	-----	
Siberia	Power Transformer *Rating: 25 MVA*	145 kV	ABB	2009	Substation Re-configuration	
Dyersburg, TN	Power Transformer *Rating: 10/13/16 MVA*	161/13.2 kV,	TVA	2006	Emergency Replacement	
Iran	Switchgear *Rating: 15 MVA*	69/132 kV	Hawker Siddeley	2002	Planned Refurbishment	
Vermont	Power Transformer *Rating: 50-MVA*	115- to 39-kV	Vermont Electric Power	2003	Substation route issues	
California	Power Transformer and switchgear *Rating: 60 MVA*	110 kV	Siemens	1994	Planned Refurbishment	
-----	Switchgear, capacitor bank	110 kV	ABB	-----	Mobile MSC	
Imperial valley	Power Transformer and switchgear *Rating: 50 MVA*	92 kV	Siemens	1999	Quick connection	
Songalaz	Power Transformer *Rating: 30 MVA*	60 / 30 kV	Matelec	2005	Planned Refurbishment	
Algeria	Step up power transformer *Rating: 18-24-30 MVA*	63-31.5/11.5 kV	ABB	2011/2012	Planned Refurbishment	

Electricity Network Innovation Competition Full Submission Appendices

Appendix 8
MSB Project: Substation Site Pictures

Electricity Network Innovation Competition Full Submission Appendices

This appendix provides some of photographs and images of extra high voltage (EHV) substation equipment which illustrates the scale and size of the challenge that developing a rapidly deployable and mobile substation will encounter.

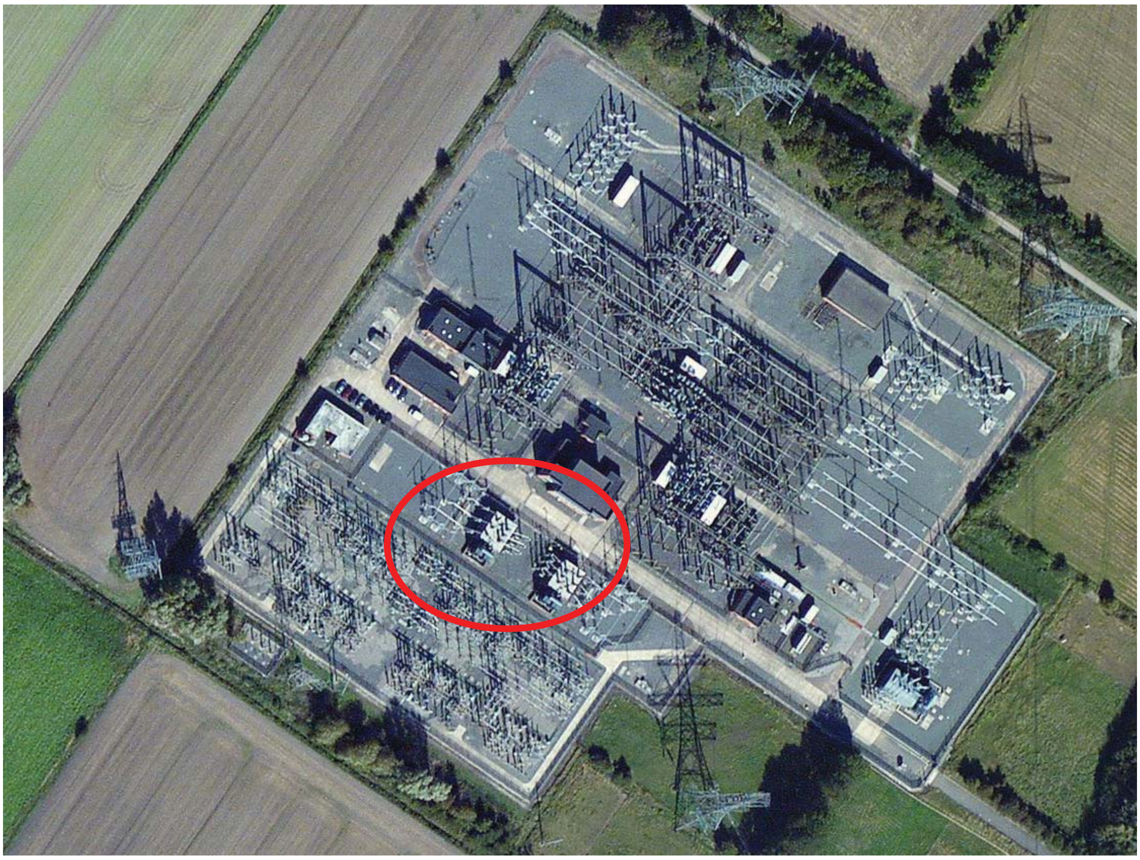


Figure 1. Aerial view of an Air Insulated Switchgear Substation

Figure 1 shows a relatively small Air Insulated Switchgear (AIS) substation, highlighting, two Supergrid Transformers. This image indicates some of the challenges faced when replacing a transformer. The substation cannot be switched off when work needs to be done, so most of the work is carried out in a live environment. This requires special working procedures to safely bring the new transformer through site to the installation location, managing the proximity to live circuits and site preparation necessary to carry out the replacement.

Figure 2. 400kV Substation Bay

Figure 2, is a photo of a standard substation bay. This comprises the equipment that the MSB project intends to redesign such that it can be rapidly deployable and easily transportable to be used in any National Grid substation. The bay includes a 240MVA 400/132kV transformer, which 400kV switchgear (left), the 240MVA 400/132kV Supergrid Transformer, cooling system for the transformer and 132kV switchgear to connect the bay to the Customer’s busbars. The scaled silhouette to the right of the image aims to provide a perspective of the bay, compared to an adult.

Figure 3. New Supergrid Transformer being transported to site

Figure 3, shows the delivery of a transformer to site. It depicts an 400kV SGT being transported to a substation that weighs around 200 tonnes. A narrow road is not an uncommon sight approaching a substation, and this photo shows the challenge of navigating some of these access roads.

Figure 4. Example of a 132kV Mobile Transformer Transportation

Figure 4, illustrates the type of solution National Grid is looking to develop, but for 400kV applications. The picture shows a 132kV transformer on a more standard sized lorry, which is much more agile vehicle than the vehicle in fig.3.

Electricity Network Innovation Competition Full Submission Pro-forma

Appendix 9
MSB Project: Steering Committee Terms of Reference

Electricity Network Innovation Competition Full Submission Pro-forma

MSB Project Steering Committee

Terms of Reference

Version 1.1 (Draft) – 1st July 2013

Electricity Network Innovation Competition Full Submission Appendices

1. Context

National Grid Electricity Transmission is accountable to Ofgem for undertaking the MSB (Mobile Substation Bays) demonstration project which is part funded through the Network Innovation Competition (NIC). NIC funding is subject to the requirements set out in Ofgem's Electricity Network Innovation Competition Governance Document and the MSB Project Direction.

Reference to the "Committee" shall mean the MSB Project Steering Committee

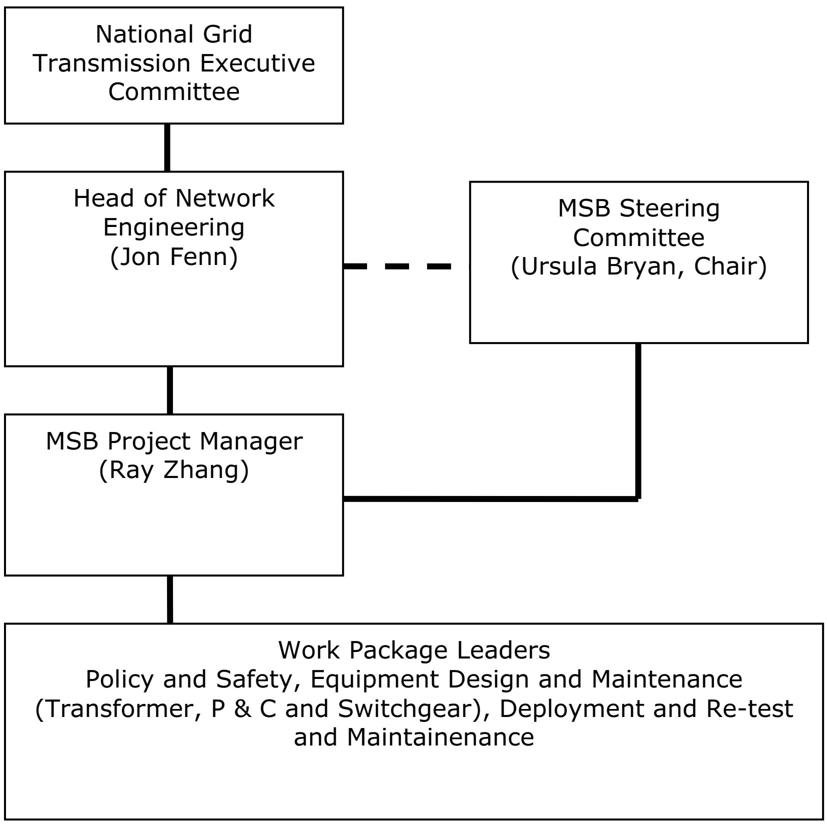
Reference to "Governance Document" shall mean the Electricity Network Innovation Competition Governance Document

2. Purpose of the Committee

The purpose of the Committee is to provide assurance that the requirements set out in the Governance Document and the Project Direction are met throughout the course of the MSB project.

3. Project Governance Structure

The following organogram depicts the lines of accountability for the governance of the MSB project.



4. Role of Committee Members

The role of the individual members and standing invitees of the Committee is to:

- Ensure the requirements of stakeholders, in particular Ofgem Governance and Project Direction, are met for the duration of the Project
- Contribute to the balancing and resolution of conflicting priorities
- Provide guidance and direction to the Project Manager and project team within their area of expertise
- Challenge and review all documentation referred to the Committee.

Members of the Committee are encouraged to take a holistic approach to Committee debates with the aim of guiding the MSB project delivery team in the most appropriate manner within the remit of the Committee.

5. Membership

The Committee shall comprise of:

		Individual Members	Standing Invitees
Name/Title	**Affiliation**	*Voting Rights*	*No Voting Rights*
Steering Committee Chair	National Grid	**X**	
Project Manager	National Grid	**X**	
NIC Manager	National Grid	**X**	
Transformer Technical Lead	National Grid	**X**	
Switchgear Technical Lead	National Grid	**X**	
Protection Technical Lead	National Grid	**X**	
Capital Delivery representative	National Grid	**X**	
Carbon Assessment Specialist	Carbon Trust		**X**
Tbc	Solution Provider	**tbc**	**tbc**

6. Convenor/Chair

Ordinarily, the Chair, shall convene the Committee meetings.

If the designated Chair is not available, then he will nominate an Acting Chair. The Acting Chair is responsible for informing the Chair as to the salient points / decisions raised and agreed to at the meeting.

7. Conflicts and Business Separation

Prior to the Committee meeting the Chair shall consider whether the Agenda will create any conflicts of interest or business separation issues. In the event that a conflict of interest or business separation issue is identified then this will be noted on the Agenda and Minutes. The Chair will consider the best way of conducting the meeting so no conflict of interest or business separation issue arises. This may include removing the item from the agenda or asking the relevant individuals to leave the meeting for the duration of the relevant agenda item(s). In such cases the agenda item in question shall be the subject of a separate Minute and shall not be circulated to the individual(s) who were asked to leave the meeting.

The Chair should seek advice from National Grid's Business Separation Compliance Officer, if necessary.

8. Frequency of Meetings

The Steering Committee will meet at least every 3 months or at any other time at the request of any of the Parties to the Project Manager specifying in reasonable detail the reason why the meeting is required. Meetings of the Steering Committee should be convened with at least twenty-one (21) days written notice in advance. That notice must include an agenda. Minutes of the meetings of the Steering Committee shall be prepared by the chair of the meeting and sent to each of the Parties within 14 days after each meeting.

The venue of each meeting will be agreed, and in default of agreement at National Grid House, Warwick.

9. Minimum Agenda Items

Each Committee meeting must consider, as a minimum, the following agenda items:

1. Project safety
2. Progress against plan
3. Progress against budget, including review of bank or other financial statement
4. Review of project risk profile
5. Evidence of progress towards completing each of the Successful Delivery Criteria
6. Achievement of learning outcomes and appropriateness of dissemination activities undertaken
7. Review of Intellectual Property issues arising
8. Feedback from Ofgem and other key stakeholders that could materially influence the remainder of the project

9. Review of plans for the coming six month period
10. Approval of project progress report/close down report
11. Vote on whether a recommendation be made for the project to be halted.

10.Meeting Attendance

Any member of the Steering Committee may participate in meetings of the Steering Committee by tele-conference, video-conference or any other technology that enables everyone participating in the meeting to communicate interactively and simultaneously with each other.

11.Proxies to Meetings

If a regular member is unable to act due to absence, illness or any other cause, the member may appoint deputy/alternate or to serve as a temporary, alternate member to act on his or her behalf as necessary. Any appointments of an alternate member for a period longer than two months in duration must be approved by the Committee Chair.

12.Quorum Requirements

In order for the Committee meeting to be recognised as an authorised meeting and for any recommendations, resolutions or approvals to be valid a quorum must be present. A quorum shall be defined as a minimum of 67% of Committee members with voting rights and must include the Chair, or his appointed nominee acting as Chair for the meeting. In case of a split vote, the Chair or Acting Chair shall have the casting vote.

Decisions shall be taken by a simple majority of a quorate meeting of the Committee.

Decisions concerning the following are subject to unanimous approval of all voting members of the Committee:

- amendment to the allocation of any funding or change to any contribution;
- the decision as to whether to reject personnel from being involved in the project or dismiss the personnel from the Project;
- whether a Party to the Project shall be permitted to audit another Party;
- amendment and updates to any anti-bribery and anti-corruption policies;
- whether a recommendation be made to National Grid & Ofgem that the Project should be terminated; and
- material changes to the Project and changes to the Results to be delivered;

For the avoidance of doubt, the Committee does not have the authority to make any amendments to the contractual arrangements between the Parties involved in the project; however, it can make recommendations to National Grid Gas to consider amendments where a simple majority of a quorate Committee are of the view that it is necessary for the successful completion of the Project.

13.Project Manager Responsibilities

The Project Manager shall:

- be responsible to the Steering Committee for the day-to-day management of the Project,
- be responsible for the financial administration of the Project as required by the Funding Conditions,
- be responsible for coordinating the implementation of decisions taken by the Steering Committee,
- be responsible for the preparation of six monthly progress reports for review and approval by the Committee, and
- Monitor the progress of the Project.

14.Review Timetable

The Committee will review these Terms of Reference and the effectiveness of the Committee every twelve months as a minimum with the first review occurring July 2015.

Electricity Network Innovation Competition Full Submission Appendices

Appendix 10
MSB Project: Base and Method Cost Details

To compare Base and Method Costs on a like for like basis is difficult because the purposes and circumstances under which the MSB could be used would be very different to current approaches. Therefore the Base costs have been based on a series of high level assumptions. These assumptions are described in the table below:

Description of Cost	**Base Cost Explanation**	**Method Cost Explanation**
Design & Development	This is the cost of Scheme Design, meaning the costs associated with developing a suitable solution in response to a needs case. The Base cost and Method cost are unlikely to vary once development of Mobile Solutions becomes Business as Usual.	This is the cost of Scheme Design, meaning the costs associated with developing a suitable solution in response to a needs case. The Base cost and Method cost are unlikely to vary once development of Mobile Solutions becomes Business as Usual.
Land & Civils	This is the cost for Civil Works which typically include land preparation, permanent foundations and oil containment that would be required when implementing a permanent transformer solution at an existing substation.	The costs for Civil works when using a Mobile Solution will be dramatically reduced due to elimination of the requirement for permanent foundations and oil containment.
Equipment	The base cost assumes all of the following equipment is acquired: Transformer, Connections, Switchgear and Protection and Control. These base costs have been validated against recent real schemes.	There will be limited equipment requirements due to the ability to redeploy the Mobile Substation Bay (see MSB charge out note below). Our method cost assumes that some sites nonetheless require additional connections and modifications to existing Protection and Control.
Installation	This is the labour and tool hire costs associated with installing permanent equipment. These base costs have been validated against	This is the labour and tool hire costs associated with installing the MSB equipment. A much shorter period of time will be spent

	recent real schemes	on site in the Method Cost scenario hence the lower cost.
MSB Charge Out Cost	Not applicable in the Base Cost Scenario.	*This is the cost associated with "hiring" the Mobile Substation Bay equipment for the period of time that it is intended to be deployed. We are assuming that the suite of MSB equipment will cost approximately [redacted] to purchase. We further assume 10 deployments of the same units and [redacted] of maintenance, refurbishment and storage between each deployment. This gives a notional charge out [redacted] per deployment.
Contingency	Contingency is set at 20% for both scenarios	Contingency is set at 20% for both scenarios

*The assumption is that 5 MSB units, with a whole operational life of ten years each, will be deployed on the network each year from 2020 onwards.

Appendix 11
MSB Project: Application Examples, Benefits Estimation and Technology Readiness

Electricity Network Innovation Competition Full Submission Appendices

This is a summary of the future potential of Mobile Substation Bay (MSB) application on the National Grid Transmission network. The assessment provides an indication of the benefits that MSBs could have provided based on the review of a number of past schemes. This has then been used to inform an estimate of the future numbers of MSB deployments and anticipated financial benefits.

Additional information has also been provided to illustrate the maturity of mobile solutions at 400kV based on dialogue with manufacturers and solution providers to date.

1. Applications

There are a number of scenarios where the provision of a rapidly deployable substation bay could yield benefits to both National Grid and its customers in terms of project efficacy and reduced capital costs. The following scenarios illustrate how the MSB could be employed to benefit the project.

1.1 Scenario 1 – Additional Capacity for "Bypass" Purpose

Figure A1 shows the MSB being used to provide additional capacity to the substation, temporarily enabling the connection of more demand without the need to extend the existing site on a permanent basis. As shown in Figure 1A substation bay 1, 2 and 3 are operating at their rated capacity while the MSB takes on the extra load for a short duration. This type of application will be useful for providing capacity for major events or major projects, where it can be anticipated that additional capacity will be needed at a location for a limited period of time, for example the Olympics which lasted just weeks, or the overlap between new generation equipment and retiring plant which may last for one or two years.

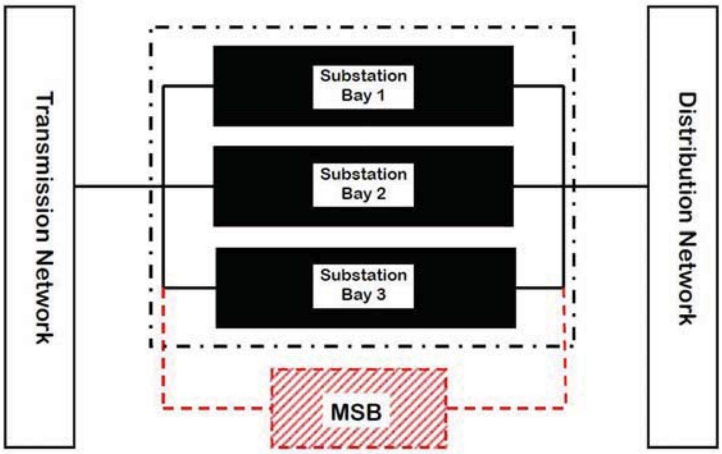


Figure A1 – Scenario 1, an MSB providing additional capacity to a substation

A similar arrangement can be also deployed for substation bay replacement or extension. Transmission substation equipment has a finite asset life and at some stage needs replacing. The criticality of many substations is such that they cannot be totally switched off. Therefore any work must be carried out in a 'live' environment. The illustration shows how two MSBs can be used to bypass the substation completely, enabling all the substation bays to be taken out of service and the work to be carried out in a safer environment. In Figure A2, bay 1 and 2 are taken offline while substation bay 3 is constructed adding an extension to the existing substation, increasing the permanent capacity.

This type of set up also illustrates how MSBs could be used for emergency restoration after a catastrophic event. The description above refers to MSBs providing support during a planned operation, however, Bay 1, 2 and 3 could also be out of operation as a result of storm or other major damaging events.

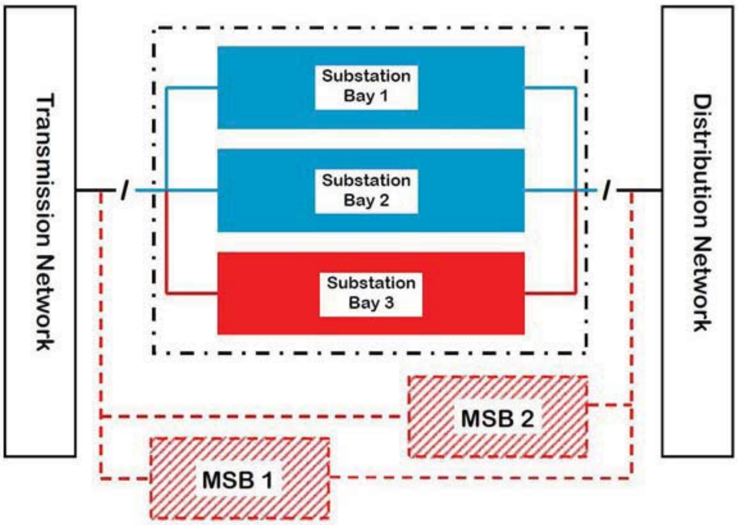


Figure A2 – Scenario 2, a pair of MSBs providing substation bypass enabling bay replacement or extension

The MSB can also be used to support efficient substation maintenance. Transmission substations are designed with redundant capacity to cater for faults and maintenance, however, in some cases network congestion due to generation limitations or adjacent construction work can make it impossible to secure outages for maintenance. As with any equipment, if maintenance is not carried out when it is required, the equipment is less likely to be as reliable or last as long as it was expected to. The example below, shown in Figure A3, is an ideal opportunity for an MSB to provide capacity that will enable substation bays 2 and 3 to be taken off line for maintenance. Although substation bay 3 is offline for maintenance work, substation bay 2 may also need to be switched out because of safety issues. This allows the work on Bay 3 to be carried out safely and quickly.

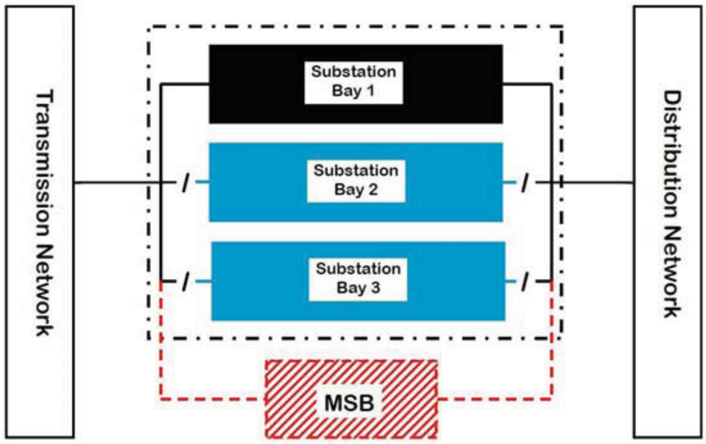


Figure A3 – Scenario 3, using an MSB to secure temporary capacity during maintenance

1.2 Scenario 2 – Accelerated Connection

Figure A4 illustrates how a wind farm under construction, could benefit from employing an MSB alongside the permanent substation solution to connect and release low carbon generation capacity early while the remainder of the wind farm is being built. Bringing the wind farm online a section at a time allows the generator to export power earlier than would be possible if the permanent substation had to be completed first. Wind farms usually comprise of several 'strings' of turbines that could be connected in a sequential manner with the MSB, allowing electricity generation and export to the grid to start before the whole farm is completed.

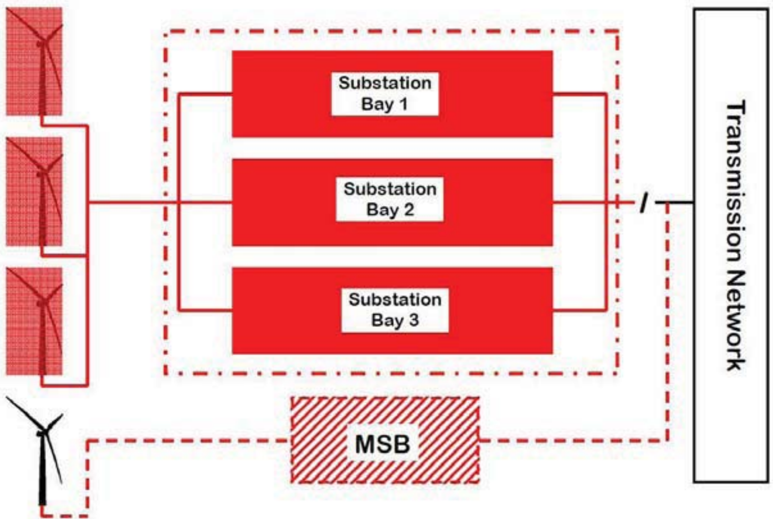
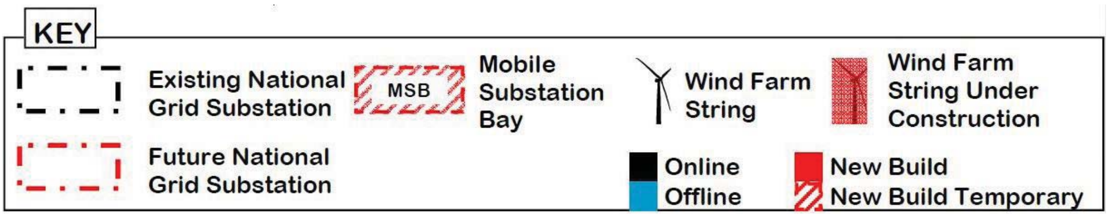


Figure A4– Scenario 4, using an MSB to release capacity early while the remainder of the power park and permanent substation is constructed



2. Quantification of MSB deployment volumes & customer benefits

A range of schemes delivered in the past as well as planned for the near future, have been considered to compare the potential efficiency of the MSB with that of a permanent solution. The assessment is high level since no two schemes are the same; and detailed design costs could not be established unless the scheme was assessed in detail and released for tender.

Table A11.1 identifies the volume of schemes where MSBs would have been considered if they had been available at the time, and future schemes where if the MSB is successful it could realise savings. The range of benefits have been based against past scheme out-turn costs.

The benefits are achieved though two mechanisms:

- via capital efficiencies on asset replacement and development projects
- early system access or increased capacity for generation.

A high level review has been carried out of 300 schemes completed in England and Wales in the last 10 years and it is estimated that approximately 5% of them (16 in number) could have benefited from a fleet of 5 MSBs. Of these 16 schemes, a high level review shows estimated project savings in the order of [redacted]ompared to an actual out-turn cost totalling [redacted] On a P50* basis this suggests that the likely savings are in the order of [redacted] over 10 years or among circa 300 schemes. The potential value to the consumer based on RIIO sharing criteria is predicted to be [redacted] (based on 52/48 pro rata sharing) over the last 10 years.

*(At this time it is believed that a 50% probability (P50) assumption is still a reasonable estimate to apply to a new innovative solution which is yet to be proven.)

The retrospective review has been used to inform likely future benefits from similar type schemes in the plan for the next 10 years including RIIO-T1 and beyond. For future benefit estimating purposes, it has been assumed that the volumes of MSB applications for asset replacement and maintenance will be similar to the past 10 years. It is projected that the deployment to reduce constraints and accelerate connection dates will increase. This increase is based on greater volumes of low carbon generators connecting to the network in the coming period than in the past and a more probabilistic approach to network development. On this basis National Grid would expect to achieve savings based on P50 of [redacted] The value to the consumer is [redacted] (based on 52/48 pro rata sharing) as illustrated in table A11.2.

Scenario	Historical (last 10 years)	Future
Asset replacement substation extensions	Swansea 400kV Mannington 400kV extension Elstree extension 400kV Stalybridge substation Grain 400kV extension Barking 400kV	Tilbury replacement 400kV Wimbledon upgrade Walpole 400kV replacement Bicker Fen 400kV Pentir 400kV extension Stoke Bardolf 400kV Hackney substation extension Seabank 400kV extension
Transformer maintenance System access constraint management Emergency restoration	Bramford 400kV extension Connor's Quay 400kV Grendon SGT Rayleigh SGT Penwortham 400kV bypass Kemsley 400kV extension Iron Acton SGT replacement	Keadby SGT West Burton SGT Burwell SGT 400kV Pembroke SGT Carrington 275kV upgrade Iver SGTCrekye beck transformers Skelton Grange SGTs
Accelerated connections	Bodelwyddan Heysham extension Cleve Hill (London Array)	Hedon 275kV Wylfa 400kV Sundon, East Claydon 400kV shunt reactors Killingholme 400kV
Scheme Costs (£)	[redacted] costs)	[redacted] (total scheme sanction range)

Table A11.1 Potential schemes where MSBs could be utilised

MSB Application to deliver	Nature of benefit	Range of savings (P50) per event £	Number of historical opportunities to use MSBs in the last 10 years	Number of projected opportunities to employ MSBs in the next 10 years	Customer benefits in next 10 years (P50) £
Reduced capital costs	MSB is used to temporarily bypass and take offline enough bays to enable large scale switchgear and substation replacement in situ possible. This avoids having to buy more land and building a new substation offline using more expensive GIS switchgear.	xxxx	xxxx	xxxx	xxxx
Reduced constraints	MSB is used to facilitate temporary connections and circuits, avoiding circuit constraints during network uprating or improvement works. This would also faciliate emergency restoration while failed or damaged equipment is being permanently addressed.	xxxx	xxxx	xxxx	xxxx
Impact due to maintenance	The ability to manage constraints by deploying MSBs will mean that outages can be taken for maintenance at the time that it is necessary rather than undertaking maintenance when it is possible. This will increase asset lifetimes and defer asset replaceme	xxxx	xxxx	xxxx	xxxx
Accelerate connection dates	Use of MSB enables the customer to connect early or reduce their cost of connection through a 'customer choice' connection, where they choose to have a quicker cheaper connection which is not compliant. This could be for generation or demand.	xxxx	xxxx	xxxx	xxxx
	Total over 10 years		**xxxx**	**xxxx**	**xxxx**

Table A11.2 Quantification of the customer benefits accrued from the use of MSB over 10 years

2.1 Calculating benefits (Ref: Table 3.2 section 3.5 of the main submission text)

Cost efficiencies and benefits associated with the use of MSBs are estimated to be achieved via two mechanisms;

- savings based on more efficient capital delivery
- opportunity for customers to increase earnings from generation or embedded energy provision through early access or increased system capacity.

The following two examples explain how customer would benefit from deployment of MSBs on transmission projects. The first is based on additional income generated by the customer through accelerated connection and the second is through savings made by National Grid on an asset replacement or substation extension project.

2.1.1 Example – Generator derived benefit

This calculation uses the utilisation factor of 30%, which is used in the carbon saving calculation and includes the charge for the use of an MSB to the generator.

This considers the potential additional income a renewable generator could earn if an MSB was used to connect it 12-18 months ahead of the firm connection date.

100MW of additional generation; 8760hrs (1yr), [redacted] 30% utilisation factor - [redacted] Suggesting additional generator income over 12-18 months could be in the order of [redacted]

The cost of deploying MSBs to support this application is estimated at [redacted] in this evaluation.

This produces a cost benefit of [redacted] A 50% probability factor has then been applied giving a discounted benefit of [redacted] (rounding off).

2.1.2 Example 2 - More Efficient Asset Replacement.

This example considers the savings consumers could get if National Grid could successfully replace a substation using Air Insulated Switchgear at the same site rather than more expensive Gas Insulated Switchgear and purchase of additional land. The MSBs facilitate the bypass of larger sections of the existing substation. Anticipated savings are calculated using the following assumptions. AIS substation replacement could be in the order of [redacted] more efficient per project, only where a new strategy using MSBs can be considered. Estimates suggest 2 MSBs will be required at [redacted] each [redacted]. This gives savings of approx [redacted] After a sharing factor of 52% of any savings with the consumer, the customer benefit is approximately [redacted] which when a

50% probability factor is applied, provides a likely consumer benefit of [redacted] per substation replacement. We currently anticipate this benefit could be realised on at least 5 schemes over the next 10 years.

2.2 Future Volumes of MSBs

The size of the GB fleet of MSBs will be very much determined by business requirements, funding mechanism as well as technology maturity. At this time the view is that it will be composed of sufficient units to manage a wide range of application scenarios. In addition, the following are also determining factors for the fleet size:

- The transformer ratio. National Grid has a number of transformer ratios. The key ones are 400/132kV, 400/275kV, 275/132kV.
- The MSB is essentially made up of three elements HV switchgear, LV switchgear and the transformer. These could be used separately if required.

The fleet size for the purpose of the cost benefit analysis over the next 10 years is estimated to be up to 5 units, comprising 2x 400/132kV MSBs, 1x 400/275kV MSB and 2x275/132kV MSB.

Site differences will have a large impact on the MSB deployment and is one of the reasons why each site installation (re-deployment) could cost over [redacted]

There will be some circumstances where the site access, layout or set down space may inhibit the use of the MSB.

3 Technology Readiness

The MSB will aim to demonstrate a 'first of its kind' solution at 400kV, however, there are discrete elements of the potential solution which have already been developed or deployed in other applications at lower voltages in different applications. Appendix 7 describes projects around the world where mobile bay technology has previously been deployed, while the list is not exhaustive, it details the high voltage applications relevant to our proposal for a solution at 400kV.

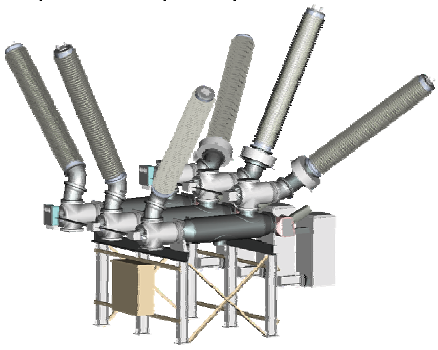
The following examples describe the state of the art technology which is likely to be applied at 400kV which are either in factory development and require field testing or have been used at lower voltages and just require 'scaling up'.

Having established further the level of technology maturity for switchgear and transportation rig solutions, it has been possible to reduce the level of project contingency for these items together with the second deployment installation contingency.

Electricity Network Innovation Competition Full Submission Appendices

3.1 Hybrid and mobile switchgear

The image is of the ABB PASS 420kV switchgear currently being type tested and should be available for a site trial in 2014. The compact design includes rotatable bushings (connections) which can be lowered for transportation and then moved into position quickly on site.



3.2 Rapidly deployable transformer

The 400kV unit was developed by ABB to provide a fast deployable solution during a construction outage. It is a single phase design (200MVA), using temporary oil bunding to protect the environment (in case there is an oil leak). This was developed for a specific application to match a three phase 350MVA unit however the principal could be used for the MSB project.

3.3 Motorised cable drum

This image is of a motorised cable drum developed by Areva (now Alstom Grid) which has been designed for frequent operation to store, transport and quickly deploy cable as part of a temporary bay installation. The application is currently suitable for use up to 145kV. The example shown is for a lower rated cable but illustrates the principle.

3.4 Temporary transformer oil bund.

This is an example of a containment solution developed by an OEM to provide environmental protection for a spare unit while it is waiting to be returned to the factory for refurbishment. This could be easily adapted for use on the MSB project.

3.5 Temporary busbar configuration.

The image is from a National Grid substation where the OEM rigged up a temporary overhead line and busbar arrangement to transfer demand around the substation, while construction was carried out in another part of the substation. This could be a method employed where the MSB cannot be located adjacent to the connection to the 400kV busbars or the customer substation.

Project Code/Version No:
NGETEN01/v2

Electricity Network Innovation Competition Full Submission Appendices

Addendum
Summary of changes compared to original submission

Electricity Network Innovation Competition Full Submission Appendices

Page/Section	Change Made
All headers	Changed to reflect that this document is version 2 (denoted by /v2)
Page 13, section 3.4	Cost comparison graph replaced with corrected version
Page 11, section 3.3	Note added to direct reader to Appendix 11 for further information about the MSB utilisation scenarios described in section 3.3
Page 14, table 3.2	Note added to direct reader to Appendix 11 for further information about the derivation of the figures provided in the table 3.2
Appendix 11	New appendix added containing additional information illustrating how it is envisage that MSB's will be used, review of schemes out of the ~300 completed in the last 10 years that could have benefited from them, forecasts of the likely future volumes MSB deployments over the next 10 years or 300 schemes and technology maturity,
Appendix 1, Cost Spreadsheet ,worksheet "2014-15" rows 29 and 32	Contingency for switchgear manufacture reduced from [redacted] Contingency for transportation rig development and manufacture reduced from [redacted]
Appendix 1, Cost Spreadsheet ,worksheet "2017-18" row 54	Contingency for installation cost for second deployment reduced [redacted]
Appendix 1, Cost Spreadsheet ,worksheet "project direction"	Cost details changed to reflect contingency changes identified above.
Page 1, section 1.4	Funding details changed to reflect contingency changes identified above.
Page 39, list of appendices	Appendix 11 and Addendum of changes identified