Modular Substation Functional Requirements

January 2016

Contents

1. Introduction

1.1 Description

1.1.1 The purpose of this document is to outline the functional requirements for modular substations and it highlights areas of the initial design where technology and opportunities exist to investigate additional benefits.

1.1.2 The document references a sample substation whose characteristics may not translate or apply to other modular substation designs. Sample datasheets in the Appendices can be used to collate design constraints based upon a specific site, as well as outline standard information required as part of a Tender return exercise.

1.1.3 The term “modular” is used to describe a new approach to substation construction. The key innovation in the modular substation is that a number of different pieces of equipment are designed to be contained in physical modules. These physical modules do not need to be enclosed on all sides as long as they are transportable as a unit. The equipment within the modules can be tested and partially pre-commissioned before being delivered to site. Once onsite, these modules can be finally connected based upon layouts of the Owners choice. The modular approach targets the following benefits:

- Faster deployment: via maximising off-site construction and programming civil works concurrently with the factory build;
- Improved whole life asset value; using equipment that may operate more times between maintenance shut downs; in turn reducing the frequency of maintenance as well as standardising the electrical designs which will enable the benefits associated with production lines to be realised;
- Increased flexibility for network configuration; matching the generation capacity requirements, via extension or swapping elements out; and
- Reduced environmental impacts: smaller geographical footprint, minimal disruption to the local communities as a result of a reduced time on-site and more sympathetic visual appearance.

1.2 Requirements

1.2.1 Modular substations aim to lower the cost, deployment times, and environmental impact of substations. The modular substation will entail assembly off site as far as reasonably practicable, designed to suit the UK transport standards, minimise requirements for civil engineering, and incorporate facilities for rapid expansions and decommissioning.

1.3 Existing System

1.3.1 The Owners of modular substations is to ensure Ratings, Protection and Control settings (Local and Remote) and any other connection parameters are developed and agreed in accordance with the relevant Transmission or Distribution Network Owner’s requirements.

1.4 Document Caveat

1.4.1 The contents of this document, including all clauses, drawings, datasheets and design principals, are produced for guidance and reference only. No analysis of relevant legal and regulatory requirements has been undertaken in the preparation of this document and legal and regulatory matters are out with its scope. The modular substation Owner may have different requirements for their equipment and any user must satisfy themselves that

the principals outlined within this document are suitable for their requirements and in compliance with all relevant legal and regulatory requirements which may be in force. **Scottish Hydro Electric Transmission plc shall not be liable to any third party that relies on any information contained within this document.**

2. Abbreviations, Definitions and Reference Documents

2.1 Abbreviations

3-D	Three dimensional
BS	British Standard
BS EN	British Standard European Norm
BS ISO	British Standard International Standard Organisation
DC	Direct Current
ENA ER	Energy Networks Associations Engineering Recommendation
ENA TS	Energy Networks Associations Technical Specifications
IEC	International Electrotechnical Commission
LVAC	Low voltage Alternating Current
MCOP	Metering Code of practice
SF_6	Sulphur hexafluoride
UK	United Kingdom
UV	Ultra-Violet

2.2 Definitions

Earth mat	Mesh of copper bars laid in the ground
Modular	A new approach to substation construction, equipment contained in physical modules.
Network Owner	The Party that maintains and owns the electrical assets at the point of connection to the existing network.
Owner	The Party undertaking the build and operation of the modular substation
Planning Authority	Grants permissions to build upon land or change land use in the UK.
Platform	Area of land required for the permanent substation, within the substation fence line
SF_6	Electrical insulating gas used in Gas Insulated Switchgear
Stakeholder	An individual or organisation that has an interest, concern or is in someway affected, by the proposals.
Tender	Seek external labour to undertake the necessary works

2.3 Reference documents

2.3.1 **Appendix A** lists a range of reference documentation, which covers many of the key aspects of an electrical substation. **Appendix A** is not a definitive list, but a starting point. The Owner will have to comply their own list of reference documentation, based upon the electrical equipment with the modular substation, the location of the connection, the Network Owners requirements and the year of design/installation. The year of design/installation is of importance as reference documentation is periodically reviewed and the modular substation design should be based upon the most recently release versions. If there is a significant time laps between design and installation it is prudent to revisit reference documentation to check for changes and incorporate where practicable.

3. Overview

3.1 Typical Single Line Diagram

3.1.1 For the purposes of this document, the single line diagram shown in **Figure 1** has been selected as a representation of a simple 33kV generation connection to the electrical transmission network at 132kV.

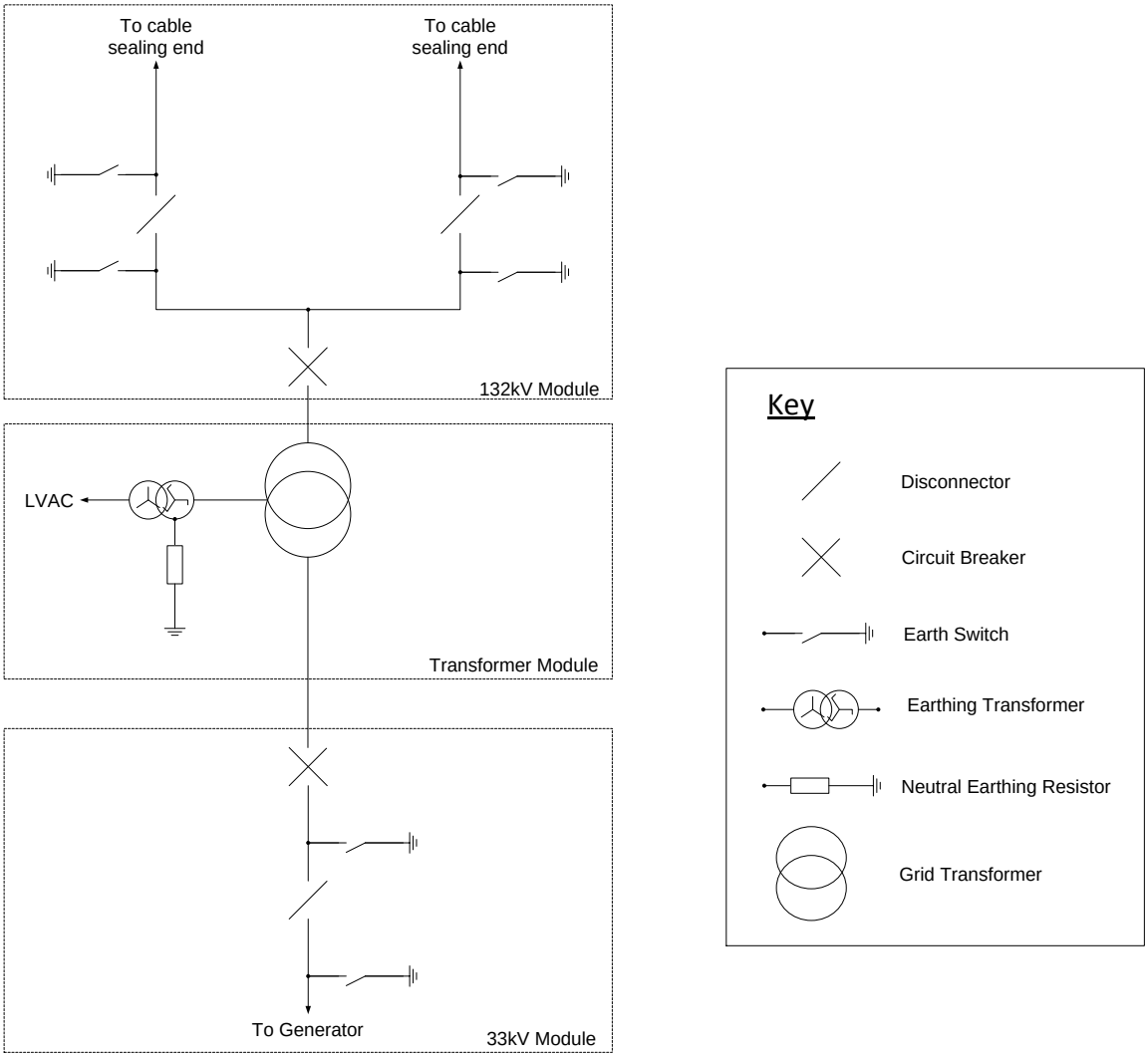
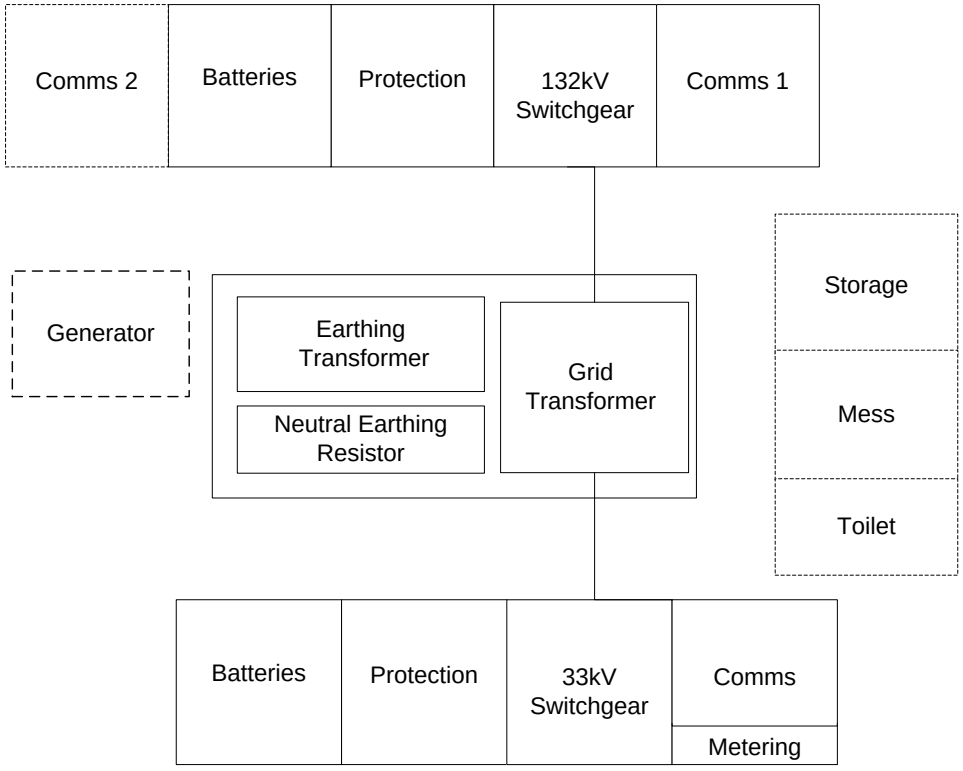


Figure 1: Typical Single Line Diagram

3.1.2 The Owner of the modular substation will be in the position of deciding the modular boundaries and the number of electrical components within each module.

3.2 Typical Module Layout

3.2.1 Below in **Figure 2** is a suggested layout of a modular substation to aid site visualisation of the substation outlined in **Figure 1**. It represents the maximum necessary elements before design refinement.



N.B. Dotted lines indicate modules which may not be required

Figure 2: Typical Module Layout

3.2.2 **Figure 2** shows five separately contained modules, which are as follows;

- 132kV module;
- Transformer module;
- 33kV module;
- Welfare module; and
- Generator module

3.3 Module Description

3.3.1 132kV Module

3.3.1.1 The 132kV module shown in **Figure 2** is a single container partitioned into separately enclosed rooms; a GIS switchgear room, a battery room, a protection room, a room for communications equipment, and a room for a second communications system if required.

3.3.1.2 Different insulation mediums are available for 132kV switchgear. The choice of insulation medium used is at the Owner's discretion. There are also 132kV switchgear products on the market that do not need to be containerised which still enable the 132kV switch to be built in the factory and shipped to site.

3.3.2 Transformer Module

3.3.2.1 The transformer module shown in **Figure 2** accommodates the grid transformer, the earthing transformer (which may also be capable of suppling power for the LVAC board) and neutral earthing resistor.

3.3.2.2 The transformer module may be enclosed or open. The operational strategy and transformer design will identify the need for an earthing transformer and neutral earthing resistor. The transformer insulation medium and the acceptable level of noise will influence the design of the transformer in both physical terms and civil engineering requirements.

3.3.2.3 A transformers capacity to transfer electrical energy is a primary parameter at the design stage. There are incentives to mirror where possible the transformers electrical energy capacity to the required generation connection capacity e.g. a 67MW onshore wind farm and a single transformer sized to transfer 67MW exactly. Prior Stakeholder engagement has identified interest in investigating further design and cost efficiencies surrounding transformer capacity. Highlighted below are several promising areas:

- Fixing the transformer capacity range; standardising on 40MW, 90MW and 120MW transformer transfer capacity, for instance. In the case of the new 67MW onshore wind farm, either two 40MW transformers or a single 90MW transformer could be used. Choosing from standard transformer sizes could reduce connection timescales.

- Future proofing the design: by designing the modular substation to facilitate the replacement of the initial transformer with a larger capacity one if required in the future.

- Combining the transformer and switchgear modules; currently possible for a 40MW transformer, but going above a 40MW transformer capacity requires development in transformer technology to reduce transformer size and enabling transportation together with the switchgear.

3.3.3 33KV Module

3.3.3.1 The 33kV module shown in **Figure 2** is a single container, which has been partitioned into separately enclosed rooms; a switchgear room, a battery room, a protection room, a room for communications, and a room for metering.

3.3.3.2 Different insulation mediums are available for 33kV switchgear. The choice of insulation medium used is at the Owner's discretion. Due to the smaller size of the 33kV switchgear, the associated protection and control equipment could be integrated with the 33kV switchgear modules.

3.3.3.3 The 33kV module may also include an auxiliary transformer if this is the preferred method of suppling the LVAC board's power requirement.

3.3.4 Welfare Module

3.3.4.1 The welfare module shown in **Figure 2** is a single container partitioned into separately enclosed rooms; storage area, mess and toilet.

3.3.4.2 There is opportunity to reduce the size of the welfare module based upon the modular substation maintenance requirements. Whilst being mindful of the applicable laws and regulations surrounding the prevision of welfare facilities.

3.3.5 Generator Module

3.3.5.1 The generator module shown in **Figure 2** consists of a stand-by generator and suitably sized fuel tank.

3.3.5.2 Understanding the auxiliary power requirements of the modular substation and the role it will play for instance in 'black-start' conditions will help design the most suitable and efficient system. The generator module may not be necessary.

4. Requirements

The sample datasheets in the Appendices can be used to collate specific design parameters or constraints, as well as outline standard information required as part of a Tender return exercise. The sample datasheets are a starting point and should be expanded and adapted to fit the needs of the Owner.

4.1 Site Selection

An outline site datasheet is contained within **Appendix B**.

4.1.1 Sites should be selected to minimise the environmental impact of the modular substation as far as is practicable. This includes for instance: available land to be developed, logistical access/egress and connection constraints associated with the existing electrical network.

4.1.2 Future expansion should be considered during site selection, with efforts made to ensure adequate space to extend the modular substation.

4.1.3 On completion of the modular substation the surround land should be landscaped to help reduce the visual impact. Landscaping should be sympathetic to the surrounding environment.

4.1.4 It would be prudent to undertake social economic analysis of the modular substation at the selected location. Through this analysis there is the opportunity to assess and quantify the impact of the sites carbon footprint, the vehicle movements and the aesthetic value for example.

4.2 Design & Operation Expectations

An outline design and operation expectation datasheet is contained within **Appendix C**.

4.2.1 The operation asset life expectancy of the modular substation should align with the associated connecting assets. As an example, an onshore wind farm has the life expectancy of 25 years, therefore the associated modular substation should also be 25 years.

4.2.2 The modular substation should be designed to require the minimum maintenance. It will be at the Owner's discretion who will carry out the maintenance. The maintenance operatives will need to be trained and their skills maintained to service the modular substation.

4.2.3 It will be at the Owner's discretion how equipment failure will be handled. Equipment may be repaired in-situ which may lead to an extend period of non-operation or a full replacement may be undertaken with the faulty equipment repaired off site. How equipment failure is managed will help to determine the level of spare equipment required and needs to be balanced against acceptable downtime periods.

4.2.4 At the desktop design stage, the boundaries or interfaces between ownership, safety operations, control operations, maintenance etc., should be defined and agreed. Identifying these boundaries or interfaces will enable metering, service contract and substation control systems to be implemented. Clear designation will also enable a more efficient transfer or sale of assets in the future.

4.2.5 The aspiration of the modular substation is that the majority of the electrical build occurs off site in a suitable location. Therefore, there should be minimal time required on-site to make the final connection between the modules and undertake commissioning.

4.2.6 The modular substation is to be as reliable, operationally available and safe to operate as today's standards, if not better.

4.2.7 Vibration monitoring equipment should be installed within the modules to monitor the transportation and installation.

4.2.8 3-Dimensional modelling of the modular substation should be considered at the initial stages, to ensure accurate measurements for lengths and volumes are calculated. The use of 3-D modelling could aid in reducing material waste or reducing the carbon footprint for instance.

4.2.9 At the design stage investigation into how other industry's reduce costs should be promoted to identify transferable knowledge and associated benefits. This refers to searching for ways to improve or increase the use of collected data to inform asset health decisions or foundation strengthening methods as examples.

4.2.10 The design for the modular substation should be risk assessed against construction, operation and maintenance activities, as a minimum. Where issues are identified, mitigation options should be detailed. The first mitigation preference should be a physical fix, with the last being operational processes. It will be at the Owner's discretion to choose the mitigation option based on their view of the likelihood of occurrence and the potential impact.

4.3 Civil Engineering

An outline civil datasheet is contained within **Appendix D**.

4.3.1 Foundations and Fencing

4.3.1.1 The area of land required for the substation or 'platform' should be minimised as far as is practicable.

4.3.1.2 The temporary land required during the construction phase to support the build of the platform, installation and substation commissioning should be minimised as far as is practicable.

4.3.1.3 The platform perimeter is normally a fence, within which the ground is level. At the design stage, the layout of the enclosed modules should be considered to identify if the enclosure could be used as a section of the platform perimeter.

4.3.1.4 Within the platform perimeter, there will be vehicle roads and structural foundations or bases, which are suitable to support the modules or equipment. The platform may have area's that do not have a specific purpose, where there are such area's a level surface which requires minimal maintenance and of minimal appeal to wildlife such as 'stone chips' should be used.

4.3.1.5 Within the platform perimeter, an analysis of the ground is required, it may be necessary to strengthen the ground to make it suitable to hold the planned modules and equipment. The method of strengthening the ground is at the Owners discretion.

4.3.1.6 The modules may be raised above the level of the platform, based upon cable entry requirements from underneath the module. The alternative would be a cable basement to facilitate the bending radius of the cables beneath the module. Basements below the platform ground level are less preferred, as

they can be deemed to be a confined space and are prone to flooding. It is prudent were possible to design out these potential risks. Raising modules that require cable entries from beneath the module is at the Owner's discretion.

4.3.1.7 The structural foundations or base may require a smaller volume of material if the modules are raised upon legs, as individual bases supporting only the legs may be required as opposed to bases, which are the length and breadth of the module. The level of optimisation of the base is at the Owner's discretion.

4.3.1.8 The use of precast concrete foundations should be considered to reduce the volume of wet concrete used on site.

4.3.1.9 Permanent equipment such as transformers, auxiliary generators, that contain fluids that have the potential to pollute the environment require suitable containment systems. At the design stage, there is a range of options that could be considered; from the use of non-polluting fluids through to different containment options. The containment system may be built into the foundation structures via the construction of a bund, which may be poured in-situ or consist of precast structures bonded/sealed once placed in the ground. Containment systems may also be a correctly sized tank upon which the equipment is placed. This is at the Owner's discretion and may be influenced by their discussion with the Environmental Authority.

4.3.1.10 Access will be required from the road system to the platform location. The use of trackway for provision of site roads should be considered to minimise land scarring post platform construction for example.

4.3.1.11 Where reasonably practicable, dual access/egress to the platform should be designed to remove the need to provide for large vehicles turning on site.

4.3.1.12 Cranage may be the preference to lift the modules and equipment onto their permanent locations on-site. If this is the case then hardstanding area's suitable for the cranes need to be considered. There will be options surrounding the hardstanding area based upon the size of crane, the crane's reach and provision for use of the crane post construction. These all need to be factored into the initial design.

4.3.2 Drainage and Substance Containment

4.3.2.1 Perimeter drainage should be provided to prevent through flow of water across the site.

4.3.2.2 There should be suitable plumbing for welfare facilities to ensure no controlled substances are released to the environment.

4.3.2.3 Provisions should be made to ensure that no controlled substances are released to the environment. There should be suitable drainage provision with interceptor tanks (or similar).

4.3.2.4 Provisions for drainage of non-controlled substances should be agreed, with the relevant Local Planning Authority.

4.3.2.5 4.3.2.1 to 4.3.2.4 should also be applicable to the temporary works areas.

Where it is impractical for the temporary works areas, then suitable water containment/treatment measures should be in place. For example, temporary welfare facilities with the waste products contained in serviced tanks.

4.3.2.6 Water discharge licenses may be required.

4.3.2.7 At the Owner's discretion consideration at the design stage should be given, to the using a geo-membrane type material at the perimeter of the site to prevent movement of contamination both within and from outside sources. Understanding the level of risk of internal pollution and the location of the substation and the surroundings will strongly influence whether or not this is considered.

4.3.3 Roads and Parking

4.3.3.1 There should be clear roadways/paths to ensure safe passageways for vehicles and personnel. This should apply to both the permanent and temporary sites

4.3.3.2 Use of plastic at grade solutions for the provision of walkways should be considered.

4.3.3.3 There should be parking for personnel and maintenance vehicles on site to suit the maintenance requirements of the substation.

4.3.3.4 4.3.3.1 to 4.3.3.3 should also be applicable were possible to the temporary works areas.

4.3.4 Lighting

4.3.4.1 The design of flood lighting should be assessed based upon the location of the site and its intended use. There is unlikely to be a need for it to be permanently switched on.

4.3.4.2 External lighting that integrates with, or which mounts on enclosures is preferred.

4.3.4.3 The illumination levels of the external lighting should be designed in accordance with recommend levels based upon the intended operations. For example, a road may require a lower level of illumination than an area designated for equipment inspection.

4.3.4.5 4.3.4.1 to 4.3.4.3 should also be applicable were possible to the temporary work areas.

4.4 Enclosures

An outline enclosure datasheet is contained within **Appendix E**.

4.4.1 Enclosure Construction and Layout

4.4.1.1 The modules to be enclosed and the level of enclosure required is at the Owner's discretion. For example, the actual transformer will not be enclosed, however the associated protection, control and monitoring equipment is to be housed in the switchgear module.

4.4.1.2 Enclosed modules should be weatherproof, resilient to the environment in which they are to be situated and require minimal maintenance for the duration of the stated operational lifetime.

4.4.1.3 Non-conducting materials are preferred for the walls and ceiling of the module. Where metal is used as part of the enclosure, it must be suitably earthed to protect personnel from any form of electric shock.

4.4.1.4 The enclosure needs to be structurally strengthened, to withstand the transportation from the factory with equipment already installed to the permanent substation site. It also needs to be structurally capable to withstand the chosen method of installation on-site. For example, if it is to be craned, then internal supports as well as lifting eyes need to be designed in. There are a number of options available for the on-site installation of the enclosure, the choice is at the Owner's discretion.

4.4.1.5 The external finish of the enclosure should be in line with the any commitments agreed with the Planning Authorities or residents within the local area.

4.4.1.6 The enclosure should be designed to be vandal proof to the extent reasonably practicable. Also recommended are high security doors with suitable locking arrangements.

4.4.1.7 The enclosure doors should be sized such as to allow the removal of the largest foreseeable single piece of equipment contained within.

4.4.1.8 The enclosure may require more than one door into an area. This will depend on the type of equipment being housed and escape routes for personnel in the event of equipment failure.

4.4.1.9 The equipment housed within the enclosure may need to be accessed from the front and the back, in these cases the equipment should be located within the enclosure to permit suitable access.

4.4.1.10 The enclosure where practicable should be designed to withstand the failure of the equipment housed within.

4.4.1.11 Consideration should be given to raising and supporting the modules above the level of the platform at the design stage, given the locations flood risk and cable entry. The height of the module above the platform is at the Owner's discretion.

4.4.1.12 When modules are raised, suitable methods of access and egress needs to be designed for personnel and equipment.

4.4.1.13 As the enclosure is housing electrical equipment, it may be necessary to run electrical connections between modules. The electrical connections may be in the form of cables or bus-bars. When this is necessary, the exit and entry of the electrical connections need to be designed accordingly.

4.4.1.14 There must be consideration given to the location of electrical connections within the enclosure, to ensure that any necessary commissioning testing can be accommodated.

4.4.1.15 There should be suitable weather and UV light resistant labelling of each enclosure from the outside. The labelling should be clear and unambiguous.

4.4.2 Enclosure Services

4.4.2.1 Enclosures will require sockets for electrical equipment. The voltage level, the location and the number should be based upon the commissioning, inspection, operational and maintenance requirements.

4.4.2.2 Enclosures will require a communications network to support telephony, protection & control equipment, substation control systems and electricity metering units.

4.4.2.3 Enclosures may require water.

4.4.2.4 Enclosures may require a fire detection system.

4.4.2.5 Enclosures may require intruder alarm systems.

4.4.2.6 Enclosures that contain equipment with SF_6, which indicates the current levels, should also have this information visible external to the enclosure to prevent uninformed entry.

4.4.2.7 Internal lighting design, both standard and emergency, within the enclosures, should be sufficient to enable personnel to perform their operational and maintenance roles.

4.4.2.8 The enclosure will require sufficient heating, dehumidification and air-conditioning, to sustain a minimum and maximum operational environment level inline with the equipment manufactures recommendations.

4.4.2.9 Any service or support structure where appropriate must be earthed to the enclosures system.

4.4.2.10 Services should be clearly labelled.

4.5 Earthing

4.5.1 Earthing systems should be designed based upon site specific earthing studies and should comply with UK requirements as a minimum, if not specified elsewhere, for instance in system connection requirements.

4.5.2 Compliance with earthing requirements normally requires a suitable sized earth mat (a mesh of copper bars laid in the ground) to be installed over the substation platform. Any item within the substation platform that has the potential to conduct electricity must be connected to the earth mat.

4.5.3 Each module is to have its own internal earthing system. This will allow the equipment housed within the module, as well as any item with the potential of conducting electricity, to be internally connected to an appropriate point on the earth mat.

4.6 Primary Electrical Connection between Modules

An outline electrical connection between modules datasheet is contained within **Appendix F**.

There are options surrounding how the primary electrical connections are made between the modules. It will be at the Owner's discretion to select the most appropriate method to achieve this.

4.6.1 Cabling

4.6.1.1 At the desk-top design phase, cable routes or corridors should be identified and optimised between the modules.

4.6.1.2 Cables connecting modules may run above ground, in shallow lined trenches with removable covers or directly buried in the ground. Each of the options has its risks and will influence the cable installation costs.

4.6.1.3 There are options surrounding the entry methods of cables into the modules. The larger the diameter of the cable, the more space required to change from horizontal to vertical orientation. If the preference is underneath the module, either a cable basement within the foundation will be required or alternatively the module could be raised and supported. This will be at the Owner's discretion.

4.6.1.4 Vehicle crossing of cables should be avoid were possible. If it is necessary for a vehicle to cross a cable, the cable covering needs to be suitably rated to support the maximum perceived vehicle weight.

4.6.1.5 All cables and cables routes should be suitably labelled as Live High Voltage Cabling. The labelling should be identical and consistent across the site.

4.6.2 Alternative to Cables

4.6.2.1 Gas or air insulated bus-bars may be used as an alternative to cabling. There are advantages and disadvantages with both which need to be taken into consideration when selecting the preferred option.

4.6.2.2 At the desk-top design phase the bus-bar routes or corridors should be identified and optimised between the modules.

4.6.2.3 Bus-bar will require specialised connection equipment to join to the primary electrical equipment, as well as points where it transitions into or out of the modular enclosures.

4.6.2.4 The bus-bar arrangement should as a minimum comply with UK safety clearances, between the current carrying conductor and support structures/equipment.

4.6.2.5 Vehicle crossing under the path of bus-bars should be avoided.

4.6.2.6 All bus-bars and bus-bar routes should be suitably labelled as Live High Voltage bus-bars. The labelling should be identical and consistent across the site.

4.7 Switchgear Modules

An outline switchgear modules datasheet is contained within **Appendix G**.

4.7.1 An overview of the contents of a typical switchgear module is shared in 2.3.1 and 2.3.3.

4.7.2 The actual breaker(s) associated with the switchgear modules may or may not be housed in the enclosure. However, it should arrive on site assembled and tested as far as practically possible.

4.7.3 The type of insulation medium used in the actual breaker(s) associated with the switchgear modules is at the Owner's discretion. There are pros and cons to each type of insulation medium. As there is a general trend to reduce the size of the breaker, the insulation medium requires a higher electrical arcing resistance, which has a knock on effect on costs.

4.7.4 SF_6 has been a commonly used insulation medium, but there is a move away from its use as it is an environmental hazard and very harmful to personnel. Alternative replacements for SF_6 are under investigation and trial. If SF_6 is selected as the preferred insulation medium, it will also be necessary to install detection systems and have robust process and management policies in place.

4.7.5 There are breaker options at 132kV or high voltages that combine the earth switches & disconnectors within the same insulation chamber i.e. an electrically compact solution. It will be at the Owner's discretion as to whether or not they are used. If selected it will be necessary to define the associated maintenance policies and agree a safe system of working on the breaker.

4.7.6 There are options for 33kV and below switchgear modules that have the necessary protection and control panels included in the breaker units. If selected there should be a workable solution for on-site remote testing; to prevent personnel standing in front of the breaker under test.

4.7.7 The 33kV switchgear module may include an auxiliary transformer. This will be dependant on the design and preferences of the Owner regarding the LVAC supplies.

4.7.8 Where more then one switchgear module is procured for a site, there may be an opportunity to combine necessary elements, such as the batteries for example. Rationalisation and sharing of switchgear elements should be assessed at the desk-top design phase and be mindful of present and potential ownership boundaries.

4.7.9 Within the enclosed switchgear modules there may be partitioned rooms. All partitioned rooms must have separate external doors.

4.7.10 Based on ownership boundaries there will be a need to accommodate fiscal metering somewhere within or beside the switchgear modules. The fiscal metering will require data from electrical measurement instrumentation, power and communication services. The fiscal metering will be read by an independent party. This should be taken into consideration when identifying a suitable location.

4.7.11 The equipment within the switchgear modules is to be labelled clearly, consistently and in line with the Owner's preference.

4.8 Transformer Module

An outline transformer datasheet is contained within **Appendix H**.

4.8.1 The actual transformer, the associated earthing transformer and neutral earthing resistor may or may not be enclosed.

4.8.2 The earthing transformer and neutral earthing resistor may or may not be required.

4.8.3 The earthing transformer may be used to supply the auxiliary power requirements for the LVAC board.

4.8.4 There are a number of options associated with cooling the transformer, such as forced cooling or natural for example. There are pros and cons with each option, namely noise and investigation is necessary to help select the most appropriate combination.

4.8.5 There are different cooling fluid options for the transformer, such as water or solid resin for example. Each coolant has pros and cons, namely the coolant containment system. Investigation into the options and associated costs is necessary to help select the most appropriate option.

4.8.6 Where transformer liquid coolant is used and there is the potential of damage to the environment, if it were to leak, a containment system should be designed. It is prudent to design the containment system to hold a volume greater then the potential lost liquid, this will allow for a small accumulation of rain water for instance.

4.8.7 The material used for the transformer and its quantity will influence the electrical losses and operational life. Over time associated electrical losses can equate to significant lost revenue. Likewise, the transformer loading characteristics may allow a design that has less conductive material. It will be at the Owner's discretion where material savings should be designed into the transformer.

4.8.8 Transformers whilst in operation produce noise as a by-product. Noise assessments prior and post installation will be necessary. Transformer maximum operational noise level for the site should be defined. The transformer manufacturer has a limited number of options to reduce the associated noise, beyond this the location of the transformer and noise enclosures measures may be necessary. As previously mentioned transformer cooling accounts for a large proportion of the noise, however enclosures around the coolers will adversely affect their cooling ability.

4.8.9 The position and location of the transformer onsite needs to ensure that removal post installation is possible.

4.8.10 The equipment within the transformer modules is to be labelled clearly, consistently and in line with the Owner's preference.

4.9 Protection and Control

An outline protection and control datasheet is contained within **Appendix I**.

4.9.1 Protection and Control System

4.9.1.1 This section contains information about the electrical monitoring instrumentation, the equipment that reacts to the detection of abnormal electrical conditions, and the systems in place to remotely control the electrical equipment, which is primarily opening and closing of the switchgear. There are a number of options associated with the protection and control systems and they will be at the Owner's discretion.

4.9.1.2 The aspiration of the modular substation is having the protection and control systems installed and tested as far as practically possible whilst in the offsite location.

4.9.1.3 The protection and control systems are to be labelled clearly, consistently and in line with the Owner's preference.

4.9.2 Instrumentation

4.9.1.1 Electrical instrumentation for monitoring purposes is fitted during the primary electrical equipment manufacturing phase and is integral to the equipment. Equipment manufacturers normally detail their standard monitoring instrumentation which comes included; there will be an opportunity at the desk-top design phase to order additional instrumentation if necessary.

4.9.1.2 Electrical monitoring instrumentation primarily measures the flow of electrical current and the voltage via hard-wired current and voltage transformers. These are placed at key locations on the primary electrical equipment.

4.9.1.3 The primary electrical equipment may also come with additional monitoring functions such as temperature or status.

4.9.1.4 Any monitoring instrumentation should comply as a minimum with UK regulations.

4.9.1.5 Instrumentation is moving towards using fibre optic detection systems. Investigating their ability, reliability and associated requirements should be undertaken to determine their application within a modular substation.

4.9.1.6 Switchgear, transformer and cable manufactures are starting to offer enhanced monitoring and analysis of their equipment. Investigation into the benefits of more information and effect on the equipment operation needs to be undertaken to ensure value for money prior to the purchasing of enhanced monitoring.

4.9.3 Protection Systems

4.9.2.1 The information from the electrical instrumentation will feed into protection panels and if a deviation from the norm is detected the system should automatically take the necessary action to maintain the safety of the equipment.

4.9.2.2 Protection systems require details of when and how to react. Minimal requirements for the UK are specified in the use of system codes. More specific information may come from the equipment manufacture or the Network Owner of the system that the substation will be connected to.

4.9.2.3 Driving efficiency's with regards simplifying the modular substation and standardising the protection architecture are seen as being key objectives. Replication would also enable in-situ replacement.

4.9.2.4 Protection systems normally have an identical secondary system, which is there in case there is a failure in the primary system.

4.9.2.5 Protection systems may also need to communicate reliably with remote ends or equipment outside the modular substation perimeter. The requirements of the protection system need to be identified and accommodated at the desk-top design phase. The final protection and control requirements will be at the Owner's discretion.

4.9.2.6 The protection systems will require LVAC power.

4.9.2.7 The protection systems are comprised of a large volume of wiring in and out of control blocks. Methods to enable the wiring to be plugged in and out should be investigated.

4.9.4 Control Systems

4.9.4.1 Control systems are necessary to allow both local and remote view of the equipment status and operation of the equipment.

4.9.4.2 There may be more then one control system necessary at the modular substation. The number of control systems will be determined based on ownership and operational boundaries agreed. Separation of the control systems may also be necessary if an element of the modular substation is envisaged as being sold in the future.

4.9.4.3 Control systems may require a view of information from equipment outside the modular substation.

4.9.4.4 Not all of the information from the protection systems or monitoring instrumentation needs to feed into the control systems.

4.9.4.5 The control systems will require LVAC power prior to and post fault conditions, as it is essential to the system to be maintained as long as possible.

4.9.4.6 The control system will require a communication pathway for the information to leave site or instructions to be received. There are different options with regards to the communication pathway and it is prudent to consider installing a secondary communication pathway. This will be at the Owner's discretion.

4.10 LVAC and batteries

4.10.1 LVAC systems

4.10.1.1 Low voltage AC is required for a number of reasons within the modular substation site from powering the protection and control equipment to providing the lighting for the enclosures. To calculate the size of the LVAC board all known maximum LVAC power requirements for the site must be combined as well as any known future extensions.

4.10.1.2 The LVAC systems onsite should as a minimum comply with the applicable UK regulations.

4.10.1.3 There are options surrounding the source of primary power for the LVAC board. As well as a primary source of power, as a minimum a single reserve power source is also required. The incoming power to the LVAC board may require fiscal metering. It will be at the Owner's discretion the source of

primary power and as well as the number and type of secondary power sources.

4.10.1.4 The feeders leaving the LVAC board should be split into essential and non-essential circuits. This will ensure that power is maintained during fault conditions as far as possible to the essential equipment reliant on LVAC supplies.

4.10.1.5 Metering of the outgoing LVAC feeders may be required if it supplies equipment owned by a different Party or potentially in the future could be owned by another Party. The interfaces or boundaries defined at the desk-top design phase will enable the LVAC feeders to be grouped appropriately.

4.10.1.6 The LVAC systems should be labelled clearly, consistently and in line with the Owner's preference.

4.10.2 Batteries

4.10.2.1 Electrical equipment may be designed with internal batteries to provide enough power to maintain their essential services. Where this is the case the battery will be included.

4.10.2.2 Batteries may be used as a secondary power supply to the LVAC board. If this is the case they will need to be charged continually from the LVAC board. The battery bank should be sized to meet the needs of the essential LVAC outgoing feeders for a specified period of time. It is at the Owner's discretion the size and the operational characteristics of the batteries.

4.10.2.3 Batteries can also be installed to meet the needs of the communication systems, normally 110V and 48V DC supplies. There is an option to optimise the necessary battery system if a single DC supply voltage can be agreed.

4.10.2.4 Any room were batteries are stored in banks should also contain a ventilation system to maintain the temperature within the manufactures recommended range and prevent any dangerous gas being stored within its atmosphere.

4.10.2.5 The batteries should be labelled clearly, consistently and in line with the Owner's preference.

4.11 Welfare Module

4.11.1 Permanent welfare provisions should be assessed against the projected maintenance requirements and at the Owner's discretion.

4.11.2 Where welfare elements such as a mess room are not included, alternative arrangements should be provided when personnel are present for longer periods of time.

4.11.3 When required, hardstanding area suitable for portable welfare cabins should be included. Ideally adjacent to the roadway facilitating delivery/pickup.

4.12 Generator Module

4.12.1 A generator module may or may not be required; it is at the Owner's discretion.

4.12.2 If a generator is required, it should be sized correctly to meet the required LVAC power needs.

4.12.3 The design surrounding an on-site generator will need to include fuel storage facilities and the associated requirements, such as bunding or filling up.

4.12.4 Generators also require remote start-up facilities, to ensure that it is turned over and maintained on a regular basis. This will increase the level of reliability of the generator.

Appendix A. Reference Documentation

Document	Description
BS 1052 : 1980	Specification for mild steel wire for general for general engineering purposes.
BS 148 : 2009	Reclaimed mineral insulated oils for transformers and switchgear
BS 1710	Specification for identification of pipelines and services
BS 21 : 1985	Specification for pipe threads for tubes and fittings where pressure-tight joints are made on threads (metric dimensions)
BS 3506 : 1969	Specification for un-plasticized PVC pipe for industrial uses.
BS 4592-1:2006	Industrial type flooring and stair treads. Metal open bar gratings. Specification
BS 4592-4:2006	Industrial type flooring and stair treads. Glass reinforced plastics (GRP) open bar gratings. Specification
BS 4999	General requirements for rotating electrical machines
BS 5000	Rotating electrical machines of particular types or for particular applications
BS 5467	Electric cables. Thermosetting insulated, armoured cables for voltages of 600/1000 V and 1900/3300 V
BS 5911-1:2002+A2:2010 **BS 5911-3:2010** **BS 5911-4:2002+A2:2010** **BS 5911-5:2004+A1:2010** **BS 5911-6:2004+A1:2010**	Precast concrete pipes, fittings and ancillary products.
BS 6133 (1995)	Code of practice for safe operation of lead-acid stationary batteries
BS 6290-2 (1999)	Lead-acid stationary cells and batteries. Specification for the high-performance Planté positive type
BS 65 : 1991	Specification for vitrified clay pipes, fittings and ducts also flexible mechanical joints for use solely with surface water pipes and fittings
BS 7354 (1990) inc amendment 1	Code of practise for design of high-voltage open-terminal stations
BS 7578	Coupling Capacitors and Capacitor Dividers

Document	Description
BS 7668:2004	Weldable structural steels, hot finished structural hollow sections in weather resistant steels, specification.
BS 7671	17th Edition Requirements for electrical installations.
BS 7870: 2011	LV and MV polymeric insulated cables for use by distribution and generation utilities
BS 7888	Test requirements on accessories for use on power cables
BS 7912	Power Cables with XLPE insulation and metallic sheath, and their accessories, for rated voltages from 66kV (Um=72.5kV to 132kV (Um=145kV) – Requirements and test methods
BS EN 10029:2010	Hot-rolled steel plates 3 mm thick or above, tolerances on dimensions and shape.
BS EN 10056-1:1999	Specification for structural steel equal and unequal angles. Dimensions
BS EN 1011 -2: 2001	Welding. Recommendations for welding of metallic materials. Arc welding of ferritic steels.
BS EN 1011-1:2009	Welding. Recommendations for welding of metallic materials. General guidance for arc welding.
BS EN 10255 : 2004	Non Alloy Steel Tubes suitable for welding and threading. Technical delivery conditions.
BS EN 124:1994	Gully tops and manhole tops for vehicular and pedestrian areas. Design requirements, type testing, marking, quality control
BS EN 12620 : 2002 + A1:2008	Aggregates for Concrete
BS EN 13055 – 1 : 2002	Lightweight aggregates. Lightweight aggregates for concrete, mortar and grout
BS EN 13438:2005	Paints and varnishes. Powder organic coatings for galvanized or sherardised steel products for construction purposes.
BS EN 1461:2009	Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods.
BS EN 1991-1-1:2002	Eurocode 1. Actions on structures. General actions. Densities, self-weight, imposed loads for buildings
BS EN 1991-1-7:2006	Eurocode 1. Actions on structures. General actions. Accidental actions
BS EN 1992-1-1:2004	Eurocode 2. Design of concrete structures. General rules and rules for buildings

Document	Description
BS EN 1997-1:2004	Eurocode 7. Geotechnical design. General rule.
BS EN 295-1:1991 **BS EN 295-2:1991** **BS EN 295-3:2012** **BS EN 295-4:1995** **BS EN 295-5:1994** **BS EN 295-6:1996** **BS EN 295-7:1996** **BS EN 295-10:2005**	Vitrified clay pipes and fittings and pipe joints for drains and sewers.
BS EN 50181	Plug-in type bushings above 1kV up to 36kV
BS EN 5025	Electric cables. Low voltage energy cables of rated voltages up to and including 450/750 V (U0/U).
BS EN 50307	Lead and lead alloys – lead and lead alloy sheaths and sleeves of electric cables.
BS EN 50341-3	Overhead Electrical Lines Exceeding AC 45kV
BS EN 50341-3-9	OHL exceeding 45kV National normative aspects for the UK and NI.
BS EN 50482	Instrument transformers. Three-phase inductive voltage transformers having Um up to 52kV
BS EN 60068	Environmental testing
BS EN 60137	Insulated bushings for AC voltages above 1kV
BS EN 60228	Conductors of insulated cables
BS EN 60255	Electrical relays
BS EN 6044 - 1	Instrument Transformers – Current Transformers
BS EN 6044 - 2	Instrument Transformers – Inductive Voltage Transformers
BS EN 6044 - 5	Instrument Transformers – Capacitive Voltage Transformers
BS EN 6044 - 6	Instrument Transformers – Current Transformers
BS EN 60529	Degrees of protection provided by enclosures (IP Code)
BS EN 60694	Common specifications for high voltage switchgear and control gear standards

Document	Description
BS EN 60865-1	Short Circuit Currents – Calculation Of Effects (Part 1 & 2)
BS EN 61000	Electromagnetic Compatibility
BS EN 61439-1	Low-voltage switchgear and control gear assemblies. General rules
BS EN 61439-2	Low-voltage switchgear and control gear assemblies. Power switchgear and control gear assemblies
BS EN 61869-2	Instrument transformers. Additional requirements for current transformers
BS EN 61869-3	Instrument transformers. Additional requirements for inductive voltage transformers
BS EN 61869-5	Instrument transformers. Additional requirements for capacitor voltage transformers
BS EN 62271-1	High-voltage switchgear and control gear. Common specifications.
BS EN 62271-100	High-Voltage switchgear and control gear. Alternating current circuit breakers
BS EN 62271-102	High-Voltage switchgear and controlgear. Alternating current disconnectors and earthing switches.
BS EN 62271-103	High-voltage switchgear and controlgear: Switches for rated voltages above 1 kV up to and including 52 kV
BS EN 62271-110	High Voltage Switchgear and Control Gear: Inductive Load Switching
BS EN 62271-200	AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV
BS EN 62271-201	A.C insulation - enclosed switchgear and control gear for rated voltages above 1kV and up to and including 52kV.
BS EN 62271-302	High-voltage switchgear and control gear - Part 302: Alternating current circuit-breakers with intentionally non-simultaneous pole operation
BS EN 771-1:2011	Specification for masonry units. Clay masonry units.
BS EN 772-3:1998	Methods of test for masonry units. Determination of net volume and percentage of voids of clay masonry units by hydrostatic weighing
BS EN 772-7:1998	Methods of test for masonry units. Determination of water absorption of clay masonry damp proof course units by boiling in

Document	Description
	water
BS EN ISO 18286:2010	Hot-rolled stainless steel plates, tolerances on dimensions and shape.
BS EN ISO 9001	Quality management systems – requirements
BS EN60947 -1	Specification for low-voltage switchgear and control gear. General rules
BS EN60947 -2	Low-voltage switchgear and control gear. Circuit-breakers
BS EN60947 -3	Low-voltage switchgear and control gear. Switches, disconnectors, switch-disconnectors and fuse-combination units
BS EN60947 -4	Low-voltage switchgear and control gear. Contactors and motor-starters — Electromechanical contactors and motor-starters
BS ISO 3046	Reciprocating internal combustion engines
BS ISO 7967	Reciprocating internal combustion engines
BS1449 – 1.1:1991	Steel plate, sheet and strip. Carbon and carbon-manganese plate, sheet and strip.
BS1722 - 12: 2006	Fences. Specification for steel palisade fences
BS4 - 1:2005	Structural steel sections. Specification for hot rolled sections.
BS4190: 2001	Specification for ISO metric black hexagon bolts, screws and nuts
BS4320:1968	Specification for metal washers for general engineering purposes. Metric series
BS4652: 1995	Specification for zinc-rich priming paint (organic media)
BS4933: 2010	Specification for ISO metric black cup and countersunk head bolts and screws with hexagon nuts
ENA E/R C55	Engineering recommendation for insulated sheath power cable systems
ENA ER G19	Substation Black Start Resilience
ENA ER S34	A guide for assessing the Rise Of Earth Potential at substation sites.
ENA ER S36	Identification and Recording of Hot Sites; Joint Electrical Industry/ British Telecom Procedure
ENA G5/4	Planning recommendations for harmonic voltage distortion and the connection of non linear equipment to transmission systems

Document	Description
	and distribution networks in the UK.
ENA G59	Recommendations For The Connection Of Generating Plant To The Distribution Systems Of Licensed Distribution Network Operators
ENA TS 09-3	33kV impregnated paper insulated fluid filled and gas pressure type cable systems
ENA TS 12-11	Dry Cable Terminations in HV Switchgear for service rated voltage 12, 24 and 36kV
ENA TS 12-15	Standard circuit diagrams for equipment in 132kV substations.
ENA TS 12-23	Energy Networks Association Technical Specification for: Polyethylene Protection Tape and Polyethylene Protection Tiles for Buried Electricity Supply Cable
ENA TS 41-24	Guidelines for Design, Installation, Testing and Maintenance of Main Earthing Systems in substations
ENA TS 41-36	Distribution Switchgear for service up to 36kV
ENA TS 41-37	Switchgear for use on 66kV to 132kV Distribution Systems
ENA TS 41-37 Part 1	Switchgear for use on 66 & 132 kV Distribution Systems
ENA TS 41-37 Part 2	GIS Switchgear for use on 66 & 132 kV Distribution Systems
ENA TS 41-37 Part 3	Circuit Breakers for use on 66 & 132 kV Distribution Systems
ENA TS 43-94	Earth Rods and their Connectors
ENA TS 50-18	Application of Ancillary Electrical Equipment
ENA TS 50-19	Specification for standard numbering for small wiring for switchgear and transformers together with their associated relay and control panels
ENA TS-09-16	Tests on power cables with XLPE insulation and metallic sheath and their accessories, for rated voltages of 66kV (Um=72.5kV), 110kV (Um=123kV) and 132kV (Um=145kV)
ENATS 41-11	Tubular Aluminium busbars, connections and terminal fittings for 132kV outdoor substations.
ENATS 43-8	Overhead line clearances
ENATS 44-5	Testing the insulation systems of stator coils for rotating electrical machines
ENATS 50-18	Design and Application of Ancillary Electrical Equipment

Document	Description
ENATS 50-19	Standard Numbering for Small Wiring
IEC 34/1	Rotating electrical machines
IEC 60044 Pt. 1	Instrument transformers - current transformers
IEC 60056	High-voltage alternating-current circuit-breakers.
IEC 60068	Environmental testing
IEC 60129	Alternating current disconnectors and earthing switches.
IEC 60186	Voltage transformers
IEC 60255 & **IEC 61810 -7**	Electrical relays
IEC 60265-1	High-voltage switches. Part 1: High-voltage switches for rated voltages above 11kV and less than 52kV
IEC 60298	A.C. metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV
IEC 60466	A.C insulation - enclosed switchgear and control gear for rated voltages
IEC 60517	Gas-insulated metal-enclosed switchgear for rated voltages above 52kV
IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 60694	Common clauses for high-voltage switchgear and control gear standards.
IEC 60840	Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) – test methods and requirements
IEC 62271	AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV
MCOP 1	Code of Practice for the metering of Circuits with a rated capacity exceeding 100MVA for Settlement Purpose
MCOP 2	Code of Practice for the metering of Circuits with a rated capacity not exceeding 100MVA for Settlement Purpose

Appendix B. Site Datasheet

Key Information	Details
Grid Reference	*Pin-point location*
Height above sea level	*The atmospheric conditions change depending on the height above sea-level travelled. Electrical equipment can be affected by changing atmospheric conditions.*
Distance from the sea	*Seaside environments tend to be more salty and have a higher water content in the atmosphere. Electrical equipment and metals can be affected by salt and water in the air.*
Temperature Range	*Average summer and winter temperatures. Design to the extremes on the temperature range. Electrical equipment operates within an optimum temperature range. Heaters or air conditioning units may be required to maintain a suitable temperature environment for the electrical equipment.*
Wind Conditions	*Strength and direction of wind as well as maximum gusting values will ensure that the structural design of the module is robust enough.*
Precipitation	*Annual rainfall will enable the drainage systems and associated equipment to be correctly sized. In addition this information will also enable any necessary discharge licences to be applied for.*
Map of the Site and surrounding area **(1:25000, A4 size, section of map, with the site location identified)**	*Will provide information about the surrounding landscape, how populated the area is, the road system, the land usage, the land terrain etc.*
Brief description of the site location…. (providing more information on the Site, could include photographs)	*Summarise the additional information that the a map does not do justice too. Include pictures, descript what can be seen presently at the modular substation location.*
Access to site gained from …	*Location of the existing road. Has a route already been identified, if so, attach a map.*
Parameters stated or requirements defined in the conditions of the Consent or Planning Permission	*Looking for any details provided in formal documentation:* • *such as the height of structures on-site will not be higher then 15m, or* • *any civil work must take place between 1st May and 31st August, etc.*
Site surveys conducted…. **(Ground surveys / environmental surveys / earthing surveys / noise /**	*List any surveys that have been undertaken.* *Be mindful that without ground survey information, estimates surrounding the civil design of the substation are likely to be*

Key Information	Details
utility searches etc.)	*higher to balance the associated risk of the uncertainty of the ground conditions.*
Location of the nearest Telecommunication infrastructure	*Useful as it identifies a possible route for outgoing communication*
Location of the nearest Electrical Distribution infrastructure	*Useful as it identifies a possible source for site electricity*
Location of the nearest Water Service infrastructure	*Useful as it identifies a possible source for both incoming and outgoing water.*
Any other information that is note worthy surrounding the connection site …	

Appendix C. Design and Operation Expectations Datasheet

Table C1. Information associated with the modular substation operation

Key Information	Details
Modular substation Use	Permanent / Relocatable (temporary/emergency) *This information will help design a suitable transportation solution if the preference is relocatable.* *Additional detail on how often the modular substation would be moved is also worth while including, to enable a range of transportation design solution to be evaluated.*
Modular substation Operational Life	*The number of years the modular substation will be in use.*
Modular substation Maintenance preference	*Provide an aspiration for maintenance requirements of the modular substation. Discussion with manufactures highlight that maintenance free equipment is fast becoming a reality.*
Modules within the modular substation will be…..	Switchgear module ……. Transformer module ….. Welfare module …… Other module ……. *List the main modules, and their voltage levels, that are required to be placed together to form the substation.*
Interface or Ownership Boundaries between the existing system and new modular substation	Civil …… Electrical Plant …….. Protection & Control ……. Commercial Metering …….. Operational …….. Safety …… Other ……. *It is very helpful to define and agree the boundaries between the existing Network Owner and modular substation. The wider this exercise is and the more boundaries discussed and detailed will ensure that all aspects of the modular substation are optimised economically and efficiently.*

Key Information	Details
Electrical Single Line Diagram showing Electrical Ownership Boundaries	*A simple diagram showing the proposed key electrical components of the connection between the Network Owner and modular substation.*
Any other key elements associated with the modular substation operation which are worthy of note ……	

Table C2. Information associated with the modular substation connection to Network Owner

Key Information	Details
Grid Reference of the nearest existing substation	*Helpful as it may be necessary to design and build the necessary connection infrastructure to this point.*
Grid Reference to the nearest existing cable or overhead line	*Helpful as it may be necessary to design and build the necessary connection infrastructure to this point.*
Existing Network Owner	*Primarily this will either be a Transmission Owner or a Distribution Owner in the UK.*
Reason for Connection to the Electrical Network	Network Owner Extension / New Generation Connection (Developer not Self-Building) / New Generation Connection (developer Self-Building) / Other *The reason for the connection will influence the connection regulations that must be adhered to during the modular substation project.*
Description of the Connection Works the Network Owner will undertake	*Explain what the Network Owner will provide at the point of connection, this may be a switchgear bay at an existing substation or a cable / overhead line to the modular substation.*
Associated Timescale for the Network Owners Works	Consent or Planning Application Approval Expected ……. Date of first electrical back-feed ……. *If consent / planning approval is required, then the anticipated date is very important, as no construction works on-site will be progressed until this has been achieved. This date needs to be incorporated within the modular substation build programme, as the modular consent & planning processes / spend need to*

Key Information	Details
	align. *The date the Network Owner can first provide electrical energy to the modular substation is critical to progress on-site commissioning.*
Specifically for a New Generation Connection the Agreement is with..	National Grid System Operator / Distribution Owner *A new Transmission Connection requires a formal agreement with the Transmission System Operator, who will instruct the appropriate Transmission Owner.* *A new Distribution Connection is with the appropriate Distribution Owner.*
Connection Regulations to be complied with ….	**Connection & Use of System Code (CUSC)**: contractual framework for connection to, and use of, the national electricity transmission system. **Grid Code**: covers all material technical aspects relating to connections to, and the operation and use of, the national electricity transmission system. **Security & Quality of Supply (SQSS)**: sets out criteria and the methodology for the planning and operation of the National Electricity Transmission System. **System Operator – Transmission Owner Code (STC)**: defines the high-level relationship between the national electricity transmission system operator, National Grid Electricity Transmission plc (NGET), and onshore and offshore transmission Owners. **Distribution Code**: technical aspects relating to connection & use of electricity distribution licensees' distribution network. **Distribution Connection & Use of System Agreement (DCUSA)**: provides a single centralised document which relates to the connection and use of the electricity distribution networks. *The reason for the connection into the Network Owner system will help identify which of the Connection Regulations are applicable.*
Any specific connection requirements requested as part of the Connection Application or returned in the Connection Agreement …	Blackstart Services …. Frequency Response Services ….. Reactive Services ….. Specific Appendix Requirements ……

Key Information	Details
	Other …… *There is an opportunity with a new connection to provide certain 'services' that are desirable to the System Operator. Any 'service' agreed needs to be designed into the operation of the modular substation.* *With new Generation Connection Agreements there will be specific information within the Appendix's which is specific to a connection at that point in the network. It is worth drawing out anything that is unusual and that may influence the modular substation design.*
Any other key elements associated with the connection point which are worthy of note ……	

Appendix D. Civil Datasheet

Key Information	Details
Weight of the heaviest load	*To aid the design of the access / site roads / undertake structural assessments of delivery routes.*
Maximum length and width of module delivery vehicle on-site	*To aid the design of the access / site roads and determine if any public road improvements are necessary.*
Allowances for vehicle movements	*This information could be used in a swept path analysis review of the transport route which will inform public road improvement requirements and movements within the site boundary.*
Provisions for unloading equipment on-site	*How will the modules / heaviest loads be unloaded from the delivery vehicles and moved into position?* *Will cranes be required, in one or several locations? Details helpful to calculate the required bearing capacity.*
Geotechnical Investigations already undertaken	*List of surveys undertaken which will be available for review.*
Recommended geotechnical Investigations	*Further site surveys that the Contractor wishes to undertake and detail how the results of these will be used in the design.*
Treatment of excavated material on-site	*Detail the proposed treatment of spoil?* *Can this be utilised in landscaping or can a platform be constructed from site won material?*
On-site drainage	*Detail the preferred solution to treating surface water within the platform area*
Ground Improvement Techniques	*Detail the preferred ground improvement techniques if deemed necessary.*
Platform materials	*Detail the preferred materials to be used that achieve requirements for modules and movements of plant and personnel around site.*
Fencing	*Detail the type of perimeter fence. Is there a preference to use the modules in the fence line?*
Roads	*Detail the preferred make-up of access road, internal site roads.*

Preference associated with the finish of the site within the fence area	*Suggest materials for site area.*
Cables / Services / water	*Will there be a mixture of directly buried / troughed and surface mounted cables/services? Will there be dedicated cable corridors on-site? Is there scope to utilise a water permanent supply or suggested treatment of harvested water, as an example.*
Layout drawings	*Proposed layouts for internal access roads, the distance expectations between fences and structures?*
Any other information that is note worthy surrounding the civil requirements …….	

Appendix E. Enclosure Datasheet

Key Information	Details
Modules to be enclosed will be …	Example: *1. 33kV switchgear and associated infrastructure* *2. Welfare facilities* *There are several factors which need to be considered when deciding how much of the module is to be enclosed. It may be the preference not to enclose the high voltage switchgear or the transformer, however it should be suitable to enclose for the associated protection and control equipment.*
Enclosure modular fabrication location preference ….	Example: *33kV housing to be delivered to site then equipment installed and the welfare facility manufactured off-site.* *It is worth bearing in mind that the enclosures could be erected on-site and suitable for off-site fabrication of electrical equipment to be installed inside.* *There may be a trade off between time spent on-site and the cost of the enclosure. As an on-site enclosure will cost less than a container that needs to be suitable for transportation. But the on-site enclosure will lengthen the time and associated labour on-site.*
Modules fabricated off-site transportation challenges	Include the transportation survey of the local area around the site to be developed for the modular substation, if undertaken… Alternatively detail the size of roads, the steepness and known challenges leading up to the modular substation location … *The party delivering the module will need to carry out a more detailed transportation survey. The survey may for example influence the width and weight of the module, due to the transportation roads available.*
Modular Installation on-site	Example: *Skidded into place* *An opportunity to detail any preferences on how the module is to be removed from the transportation trailer and placed onsite.* *Craning the module will require an enclosure that is suitably strengthened, with appropriate lifting attachments; this will increase the cost of the enclosure. Using a crane, consideration will also require the provision of a suitable hardstanding area.*

Key Information	Details
Modules Fabricated Off-site Location	Key electrical equipment will come from ……. Locations where the modules are built ……. *Will depend on the manufacturer. The substation modules may be built in different locations. This information will be helpful in identifying transportation requirements and challenges.*
Modular enclosure material	Example: *Non conducting material such as GRP* *An opportunity to detail the preference for the material of the modules enclosure. E.g. non-conducting*
Modular enclosure maintenance requirements	Example: *Minimum maintenance* *An opportunity to detail the preference for the maintenance of the modules enclosure. E.g. minimum maintenance*
Modular enclosure external finish	*An opportunity to detail requirements such as the colour or 'look' that was agreed with local planning authorities.*
Telecommunication attached to the external of modular enclosure	*An opportunity to detail the preference for the number and type of telecommunication devices to be attached to modules enclosure.*
Cable entries into modular enclosure	*An opportunity to detail the preference as to how cables will enter the modular enclosure.*
Bus bar entries into modular enclosure	*An opportunity to detail the preference as to how bus-bars will enter the modules enclosure*
Security & Safety of the modular enclosure	The whole module ….. The doors type and size …… Locking facilities ….. Emergency exit, number and type …. *An opportunity to detail the preferences associated with the security and safety of the modules enclosure.*

Key Information	Details
Services within the modular enclosure	Illumination requirements both standard and emergency …… Heating requirements ….. Humidity / ventilation requirements …. Electrical plugs and sockets requirements … Earthing requirements ….. Acceptable methods of managing internal cabling within the container and through walls …. Acceptable methods of reconnecting internal services within the modules if for transportation reasons it is required to be broken down into smaller sections …. Fire detection requirements ….. Telecommunication requirements ….. Welfare requirements ….. Internal finish of the module …. *An opportunity to detail the key services within the modular enclosure, lighting, heating, electric plugs, telephones etc. are necessary and need to be designed in at the initial stages.*
Height of modular enclosure	*An opportunity to detail the preference for the height of the modules enclosure. There may be benefit in raising the module above ground level, if this is the preference then steps will be required to allow personal to enter, as well as a method to be identified for the removal of equipment.*
Location of equipment within the modular enclosure	*An opportunity to detail the preference for the location equipment within the modules enclosure. As there may be panels that require access both front and back, therefore they need to be placed in the middle as opposed to an auxiliary transformer which is better located in a corner behind a cage to protect personnel from electrocution.*
Any other information that is note worthy surrounding the enclosure …….	

Appendix F. Primary Electrical Connections between Modules

Table F1. Information associated with the cables

Key Information	Details
Cable Voltages / phase	*Example: Single phased 132kV cable between the transformer and the 132kV module.* *Detail the different voltages of cables required, their phasing and their purpose.*
Cable Rating and Load requirements	*Example: 33kV cables must be capable of carrying 60A continuous load all year round.* *Detail any preference in the current carrying ability of the cable. The ability of the cable to carry current will change with the temperature and seasons, the most challenging time is during periods of warm weather.*
Cable Installation	*Example: 132kV cable is to be directly buried.* *Detail the preference as to how the cable should cross the site.*
Cable Protection (physical)	*Example: If cabling is buried, cable tiles and warning tape are to be laid above the cable, prior to trench being refilled. If the cable is laid under a vehicle pathway suitable backfill or load diverting measures are to be installed.* *Detail the preference associated with protecting the cable from physical damage.*
Cable Protection (Electrical)	*Example: On long lengths of 132kV cable the installation of surge arrestors should be considered.* *Detail the preference associated with protecting the cable from electrical damage.*
Cable Monitoring	*Example: On the 132kV cable, distributed temperature sensing monitoring should be considered.* *Detail the preferences associated with cable monitoring.*
Cable Testing	*Example: The Owner's representative is to witness any cable factory acceptancy testing.* *Detail the preferences associated with cable testing.*
Cable Commissioning	*Detail the preference associated with on-site cable commissioning.*

Any other information that is note worthy surrounding the cables …….	

Table F2. Information associated with the cables which will be provided by the manufacturer

Key Information from Manufacturer	1st Cable Voltage	2nd Cable Voltage
Cable voltage range		
Cable 1-ph / 3-ph		
Cable Overall Diameter		
Cable Mass (KG/m)		
Cable bend radius (installation and static)		
Cable continuous Current Carrying capacity		
Cable fault current carrying capacity		

Table F3. Information associated with the bus-bar

Key Information	Details
Type of Bus-Bar	*Detail the type of bus-bar and the equipment it is to connect. .*
Bus-Bar Rating and Load requirements	*Detail any preference in the current carrying ability of the bus-bar.*
Bus-Bar Installation	*Detail the preference as to how the bus-bar should cross the site. It may be helpful to include drawings.*
Any other information that is note worthy surrounding the bus-bars …….	

Appendix G. Switchgear Datasheet

Key Information	Detail associated with *132kV*	Detail associated with *33kV*
Practical		
Installation location	*Indoor / outdoor* *Select preference*	*Indoor / outdoor* *Select preference*
Insulation medium	*Example: Oil* *There are a wide range of insulation mediums available, the location and the space available may rule out options. The switchgear cost will increase as the size dimensions decrease.*	*Example: hermetically sealed* *There are a wide range of insulation mediums available, the location and the space available may rule out options. The switchgear cost will increase as the size dimensions decrease.*
Temperature range based upon location of switchgear	*Minimum temperature:* *Maximum temperature:* *If the switchgear is to be housed outside then the temperature range will be the same as stated in the SITE DATASHEET. If the switchgear is indoors the temperature range is likely to differ from the SITE DATASHEET. If indoors heating / cooling systems may need to be installed to maintain the temperature within the range.*	*Minimum temperature:* *Maximum temperature:* *If the switchgear is to be housed outside then the temperature range will be the same as stated in the SITE DATASHEET. If the switchgear is indoors the temperature range is likely to differ from the SITE DATASHEET. If indoors heating / cooling systems may need to be installed to maintain the temperature within the range.*
Maintenance Requirements	*List any preferences*	*List any preferences*
Technical		
Rated Incoming Voltage	*Example: 132kV, 3ph*	*Example: 33kV, 3ph*
Rated Frequency	*50Hz typical of the UK AC network*	*50Hz typical of the UK AC network*
Rated short-duration power-frequency withstand voltage	*Example: 245kV (this value maybe stated by the manufacturer based on their equipment testing)* *The switchgear will be able to*	*Example: 66kV (this value maybe stated by the manufacturer based on their equipment testing)* *The switchgear will be able to*

(1min)	*withstand a voltage greater then the rated incoming voltage for a short time. The electrical components may influence the withstand voltage, if this is the case then the voltage level needs to be calculated and stated.*	*withstand a voltage greater then the rated incoming voltage for a short time. The electrical components may influence the withstand voltage, if this is the case then the voltage level needs to be calculated and stated.*
Rated lightning impulse withstand voltage (1.2/50us)	*Stated in kV* *Provided by the manufacturer based upon their equipment testing.*	*Stated in kV* *Provided by the manufacturer based upon their equipment testing.*
Rated normal current – busbar feeder	*Example: 2000A* *The electrical components will influence the current rating of the busbar, calculation necessary and requirements stated.*	*Example: 1000A* *The electrical components will influence the current rating of the busbar, calculation necessary and requirements stated.*
Rated short circuit-breaking current	*Stated in kA* *Provided by the manufacturer based upon their equipment testing.* *The electrical components may influence the short circuit-breaking current, calculations necessary.*	*Stated in kA* *Provided by the manufacturer based upon their equipment testing.* *The electrical components may influence the short circuit-breaking current, calculations necessary.*
Rated short-time withstand current (up to 3s)	*Stated in kA* *Provided by the manufacturer based upon their equipment testing.*	*Stated in kA* *Provided by the manufacturer based upon their equipment testing.*
Rated peak withstand current	*Stated in kA* *Provided by the manufacturer based upon their equipment testing.*	*Stated in kA* *Provided by the manufacturer based upon their equipment testing.*
Dimension of the switchgear	*Height, width, depth (normally stated in mm)*	*Height, width, depth (normally stated in mm)*
<u>Preference</u>		
Switchgear Manufacture Preferences	*List Switchgear types that are acceptable* *There may be a preference for the*	*List Switchgear types that are acceptable* *There may be a preference for the*

	type of switchgear to be used or standards it should be tested against.	*type of switchgear to be used or standards it should be tested against.*
Switchgear aspects that are not acceptable	*List aspects of the switchgear that are to be avoided.* *This may be an insulation medium, it may be manufacturer or a type of switchgear that has historically been problematic.*	*List aspects of the switchgear that are to be avoided.* *This may be an insulation medium, it may be manufacturer or a type of switchgear that has historically been problematic.*
Any other information that is note worthy surrounding the Switchgear …….		

Appendix H. Transformer Datasheet

Key Information	SI Unit	Details / Response
Highest System Voltage:		
HV	V	*Stated by Owner and details the highest level of voltage output from the transformer.*
LV	V	*Stated by Owner and detaisl the lowest level of voltage incoming to the transformer.*
Rated Voltage Ratio (at no-load & principle tap)		*Provided by manufacturer and details for each volt on the primary coil how many there will be on the secondary coil.*
Rated Minimum Continuous Power Rating at all Tap Positions	MVA	*Provided by manufacturer*
Tappings:		*Provided by manufacturer*
Type of tap-change switch		On-load / off-circuit *Detailed by the manufacturer*
Number of tap positions		*Provided by manufacturer*
Tapping range	%	*Provided by manufacturer*
Tapping steps on-load tap-changers	%	*Provided by manufacturer*
Connections:		
Vector grouping		*Provided by manufacturer*
System Conditions:		
System short circuit apparent power	MVA	HV – MVA LV – MVA *Provided by manufacturer*

Key Information	SI Unit	Details / Response
HV System Earthing:		*Example: solid* *Provided by manufacturer*
LV System Earthing:		*Provided by manufacturer*
Insulation Levels for HV windings:		
With stand Power frequency	kV	*Provided by manufacturer*
With stand Lightning impulse	kV	*Provided by manufacturer*
With stand Switching Impulse	kV	*Provided by manufacturer*
Impedance:		
Transformer impedance at continuous maximum rating at nominal tap and 75°C on CMR base. (% on 100MVA base)	%	*Provided by manufacturer*
Line Terminals:		
HV		Bushing / Cable Box *Provided by manufacturer*
LV		Bushing / Cable Box *Provided by manufacturer*
HV Neutral		*Example: HV star point to be brought out on an AIS bushing and connected to earth lead brought to ground level.* *(Test bushing may be utilised)* *Provided by manufacturer*
Horizontal co-ordinating gaps required for surge protection?		Yes / No *Provided by manufacturer*

Key Information	SI Unit	Details / Response
LV Termination Cable Sizes:		*Specified as required by manufacturer*
HV current transformers required:		*Detail how many CTs are required per phase on the transformer HV side.* *Manufacturer will outline their standard, the Owner may require more.*
Transformer Noise:		*Provided by manufacturer*
Maximum noise level from transformer	db	*May have been specified in EIA documentation used to support planning permission or set as a condition of planning permission*
Is provision for a noise enclosure required?		Yes / No
Transformer Electrical Losses:		
No-load loss	w	*Provided by manufacturer. The Owner can calculate the finance impact assocaited with the transformer.*
Load loss	w	*Provided by manufacturer. The Owner can calculate the finance impact assocaited with the transformer.*
Special Tests:		*Manufacture can provide the Owner with guidance on benefits of the test.*
Frequency Response Analysis (FRA)		Yes / No
Capacitance and power factor, Recovery Voltage Method (RVM),		Yes / No
Current Injection (Load Test)		Yes / No
Neutral Earthing Transformer:		*Provided by manufacturer*
Ratio		*Example: 11,500/400 V*
Rating of auxiliary winding	kVA	

Key Information	SI Unit	Details / Response
Impedance	%	*Example: 4.75 Ohms / ph - Zp* *12.0 Ohms / Ph - Z0*
Vector Grouping		*Example: Zy1/11*
Rating		*Example: 11kV - 625A 10 Sec*
Neutral Resistor:		*Example: 11kV –NER 10.16 Ohms*

Appendix I. Protection and Control Datasheet

Key Information	Details
Protection & Control schematic	*Provide a Key Line Diagram indicating where the instrumentation (current and voltage transformers) should be situated and where the instrumentation data is going.* *If may be necessary to produce several Key Line Diagrams to represent the feeder, transformer bays etc., as there might be too much detail to fit onto a single diagram.*
Fault Clearance times for protection relay schemes	*Name the documentation to be adhered to and if possible detail the voltage levels and target times.* *Example: 132kV and below, target fault interruption time of main in-feeding circuit 120ms, target back-up clearance time 1000ms (which is in compliance with Grid Code)*
Relay Panels which house the P&C equipment	*Detail preferences in relay panels*
Intelligent Electronic Devices, Relays & Auxiliary	*Detail preferences for Intelligent Electronic Devices, Relays and Auxiliary*
Software & Hardware	*Detail preferences surrounding software and hardware which may be associated with the P&C systems*
Current Transformer Ratings	*Detail preferences associated with the current transformers*
Voltage Transformer Ratings	*Detail preferences associated with the voltage transformers*
Wiring Specification	*P&C relay panels contain a large amount of fine wiring this is an opportunity to detail preferences, such as the wiring colour for example.*
Labelling	*Detail preferences surrounding the labelling*
Communication Systems	*Detail preference surrounding communication systems, as it will be necessary to send information/data/instructions from and to site. The method of communication and the number of pathways are also important to detail.*
Functional Requirements	*Detail the operational preferences surrounding the P&C system, as in tripping schemes.*
Test Requirements (location modular substation is	*Detail the factory acceptance tests for the individual P&C items. Also detail the testing to be undertaken prior to the module*

assembled)	*leaving the assembly location.* *The aspiration for testing P&C at this stage is right back to the Owner's remote control room This will require a suitable communication link and investment in substation control infrastructure at the assembly location. This may not be possible but there would be value in understanding the blockers or challenges.*
Test Requirements (in permanent location)	*Detail the site acceptance tests*
Equipment Life	*Detail the acceptable lifespan of the hardware and software.* *P&C equipment will have a lifespan which mirrors the modular substations requirements. The element that is unlikely to meet the modular substation lifespan is the hardware and software for the electronic equipment as this technology continually improves or is up-graded.*
Control Philosophy	*Detail as clearly as possible the operations that are to be carried out by the Bay Controller Unit, including the information that the remote control room should see.*
Fault Recorder	*Detail preferences surrounding the fault recorder.*
P&C Additional Options	*Below are a selection of additional P&C options that may or may not be suitable to be included:* • *Fault Locators: specifically for overhead lines.* • *Phasor Measurement Units: ability to module electrical energy in 3-dimensions.* • *Harmonic Monitoring: measures the distortion in the electrical energy form.* • *Point On Wave Switching: monitors the electrical energy wave form and makes the connection to the system when conditions are suitable.* • *GPS: used for synchronising.* • *Interlocking: either electrical or mechanical and will stop operations that should not occur, a safe system.*
Protection	*Detail preferences in the basic protection arrangements for the modular substation. Provide supporting detail for the P&C schematic.*
Any other information that is note worthy surrounding the Protection and Control …….	