Project No: EC.14219

Main Grid System Strength Project

Scope of Works

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Revision Record

Date	Version	Description	Author	Checked By	Approved By
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21/6/19	1.1	Updated with clarifications re. substations extensions and distribution assets relocation	Christopher David Senior Design Manager	Dorin Costan Project Director Dorin Costan Digitally signed by Dorin Costan Date: 2019.06.21 10:57:01 +09'30'	Dorin Costan Project Director

Contents

1. Overview

The Main Grid System Strength Support project involves the installation and commissioning of four high inertia synchronous condensers at strategic locations, on the South Australian 275 kV transmission network. The project scope includes:

1) Procurement, installation and commissioning of four synchronous condensers and associated equipment, with two units to be installed at Davenport 275 kV substation and two units to be installed at the Robertstown 275 kV substation; each synchronous condenser unit will be capable of contributing 575 MVA nominal 275 kV fault capability and 1,100 MWs of inertia;

2) Transmission power system integration studies to optimise the operation of the synchronous condensers and the interaction with existing reactive plant on the network;

3) Purchase of the land adjacent to the existing Robertstown substation to accommodate the deployment / installation of the synchronous condensers and the extension of the existing Robertstown substation;

4) Development of substation infrastructure, including all associated civil, primary and secondary works to integrate each synchronous condenser into the transmission network at Davenport and Robertstown. This will involve extension of both substations to accommodate the synchronous condensers and their associated equipment, with further extension for connection works where required based on the current substation layout.

   For the Davenport substation, the site works will be largely covering the configuration of the site to accommodate the two synchronous condensers, including their buildings and synchronous condensers - associated equipment – e.g. transformers, cooling and lubrication systems, as well as flywheels and pony motors. The Davenport site works will be largely re-using / reconfiguring two existing line exits and their associated Davenport substation infrastructure (including primary and secondary systems). To be noted that the respective exits were used in the past for the connection of the now de-commissioned Northern Power Station generators.

   For the Robertstown Substation, in addition to the configuration of the site to accommodate the two synchronous condensers, their buildings and their associated equipment, the existing substation is required to be expanded by adding in two new 275 kV diameters (in a circuit breaker and a half configuration).

   In each case, relocation of relevant distribution infrastructure will also be required.

5) Each synchronous condenser unit will be installed inside a machine hall that will be fitted with annexures for, synchronous condensers protection and control equipment, variable frequency drive (for the synchronous condensers starting via their dedicated pony motors), MV switchgear, battery AC and DC systems, ventilation system and rotating machinery lubrication and cooling systems.

2. Power System Planning, Integration and Testing

The following planning, integration and testing requirement are applicable for both Davenport and Robertstown Substations

1) AEMO and inter-regional coordination:
    a. Engage AEMO for due diligence during the project; and
    b. Develop AEMO Operating Agreement.
2) Develop R1 power system models (PSSe, PSCAD, Mudpack)
    a. Develop performance standards for synchronous condensers.
3) Review and modify (if required) relevant existing protection and control schemes
    a. Emergency control schemes;
    b. Special protection schemes;
    c. Voltage control schemes and reactive switching control; and
    d. Protection schemes.
4) Assess impact on relevant existing generator or load connections.
5) Assess impact on oscillatory stability, optimisation of OEM proposed Power System Stabilizer (PSS) settings and revise oscillatory stability limit advice as required.
6) Commissioning and R2 testing
    a. Demonstrate compliance against performance standards;
    b. R2 Validation of models based on field test results (PSSe and PSCAD); and
    c. AEMO acceptance of R2 model package.
7) Development of operational support materials for the ongoing operation of the new plant, including:
    a. Development of limit advice:
        i. Limit equations to manage construction outages;
        ii. Limit equations for ongoing operation after project implementation; and
        iii. Generation Dispatch Limiter (GDL) equations - where relevant.
    b. Updating of operating instructions for control room; and
    c. Development of stability and constraint equations for managing outages.

3. Synchronous Condenser Units

Each of the four synchronous condenser systems will include the equipment specified under sections 3.1 and 3.2 below. To be noted that while the majority of the equipment associated with synchronous condensers will be installed inside the synchronous condensers' buildings, the oil filled transformers will be installed outdoors, along together with the Diesel generators and cooling fans.

For clarity:

1) two buildings will be installed at Davenport; and
2) two buildings will be installed at Robertstown,

with each of the respective buildings housing one synchronous condenser and their associated equipment.

3.1 Machine Halls

The following equipment will be installed in the machine hall of the new building.

1) 129 MVA synchronous condenser unit;
2) 1100 MWs Flywheel, with vacuum pumps;
3) 2.6 MW Pony Motor;
4) Generator Line Accessory Compartment (GLAC);
5) Generator Neutral Accessory Compartment (GNAC);
6) Lube Oil System (LOS);
7) Machine control cubicle (MCC);and
8) AC distribution board for building supplies.

3.2 Annexures & Rooms

The following equipment will be installed in separate annexures or rooms within each of the new building:

3.2.1 Generator Circuit Breaker Annexure

The Generator circuit breaker (GCB, one for each synchronous condenser / associated step-up transformer) will be installed on a platform in the GCB annexure. The annexure and the platform will have two points of access.

1) The GCB unit will be fully contained to include the following components:
    a. SF6 Circuit Breakers;
    b. Motorised Disconnector;
    c. Motorised Earth Switches;
    d. Voltage Transformers; and

e. Current Transformers.

2) The Isolated Phase Bus compressors are installed in this annexure.

3.2.2 Variable Frequency Drive Room

Each Variable Frequency Drive room (one for each pony motor associated with each synchronous condenser) will contains the following:

1) Variable Frequency Drive - used for starting and braking of the associated Pony Motor;
2) MV isolation transformer (dry type).

This room is required to have positive pressure so as to prevent / limit the dust build-up in the room and thus ensure that the heat exhaust of the VFD power electronics systems will not deteriorate in time. The room will also be required to have AC conditioning fitted so as to ensure that the OEM-recommended operating temperature for the VFD can be maintained (and thus avoid derating of the VFD's power electronics).

3.2.3 Switchgear Room

The switchgear room will contain the medium / high voltage switchgear required for connection of relevant plant.

The voltage levels of the required switchgear will be determined by the synchronous condenser OEM supplier.

Accordingly, at Davenport this voltage was confirmed to be 6.6 kV, while for the Robertstown case is yet to be determined (it depends on OEM's preferences, however for practical purposes it can be assumed that same voltage level will be used for both Robertstown and Davenport switchgear).

The configuration is as follows:

1) Incomer supply from Unit Auxiliary Transformer (UAT);
2) Feeder supply to Auxiliary Transformer (AT);
3) Feeder supply to VFD Transformer;
4) Feeder supply to Voltage Transformer; and
5) 400 VAC Changeover Board.

3.2.4 Protection & Control Room

The protection and control rooms (one for each synchronous condenser building) will contain the following:

1) Step up Transformer protection system;
2) Synchronous condenser unit protection system;
3) UAT Protection and GCB management system;

4) 275 kV ICC panel;
5) SCADA panel;
6) Telecommunications panel;
7) HMI Server panel;
8) MarkVIe panel (synchronous condenser proprietary control system, applicable for Davenport, assumed to be similar or identical for Robertstown);
9) Synchronous condenser exciter panel; and
10) Fire & Security panel.

3.2.5 Battery Room

The battery room (one for each synchronous condenser building) will contain the following equipment:

1) Duplicate 110 VDC battery chargers with transfer bus capabilities;
2) Two independent sets of 110 VDC battery banks;
3) One 220 VDC battery charger; and
4) One 220 VDC battery bank.

3.2.6 CWPS Room

The CWPS room contains the equipment skid for the Closed circuit cooling water system.

The skid would contain the main pumps, standby pumps and emergency DC pumps.

3.2.7 Ancillary

The following equipment is also included as part of each synchronous condenser buildings:

1) Isolated Phase Busbar system;
2) Air Conditioning system - as required for each of the rooms;
3) Heat extractor fans (required to maintain the temperature inside the Machine Hall within prescribed limits and thus ensure synchronous condensers and associated equipment operation within tolerances defined by the OEM);
4) Filter fans – required to maintain positive pressure in the VFD room and machine hall;
5) Acoustic enclosures (or equivalent systems) – required to ensure that noise levels could be limited within prescribed limits; and
6) Firewalls between each UAT and its associated synchronous condenser building.

3.3 Outdoor Equipment

The following equipment will be installed outside of the synchronous condensers buildings, within each one of the synchronous condensers' yard:

1) 129 MVA Step Up Transformer (275kV / 15kV for Davenport, assumed equivalent for Robertstown) – one for each synchronous condenser;
2) 4 MVA Unit Auxiliary Transformer (15kV / 6.6kV for Davenport, assumed equivalent for Robertstown) – one for each synchronous condenser;
3) 2 MVA Auxiliary Transformer (6.6kV / 400 Vac for Davenport, assumed equivalent for Robertstown) with 400 Vac isolation kiosk – one for each synchronous condenser;
4) Cooling radiators and expansion tanks as part of Closed Water Cooling System – one for each synchronous condenser;
5) 275 kV Surge Arrestors – one set for each synchronous condenser;
6) Oil Water separator for Step Up Transformer Bund – one for each synchronous condenser;
7) Fire walls for Step Up Transformer – one for each synchronous condenser;
8) Outdoor lighting – one system for each synchronous condenser yard; and
9) Lightning protection – one system for each synchronous condenser yard.

4. Infrastructure Works

The sections below describes the infrastructure works required to be completed to facilitate the connection of the synchronous condenser units to the 275 kV transmission network. The scope of works covers the benching, earth grid, footings, concrete cable trenches, primary plant, secondary systems, telecommunications, switching and commissioning.

4.1 Davenport Substation

4.1.1 Civil Works

The civil works will include the design, verification, certification and construction of the following:

4.1.1.1 General Civil Works

1) Bulk earthworks for the synchronous condenser yard;
2) Internal substation access roads;
3) Access road from Port Patterson road including provision for storm water drainage along Port Patterson road;
4) Substation platform stormwater drainage and appropriate discharge point(s) that shall integrate into the peripheral site drainage of the overall development;
5) Integration of water drainage for the Davenport substation extension into the overall Davenport substation water drainage system; and
6) Substation site security fencing and gates (including temporary fencing as required);

4.1.1.2 Synchronous Condensers Yard Foundations

1) Foundations for the synchronous condenser buildings;
2) Foundations for the synchronous condenser, flywheel and pony motor – to be built inside their respective machine halls;
3) Foundations for other synchronous condensers and flywheels associated equipment - in each machine hall and annexures;
4) Foundations and bund walls for the for the Step Up Transformer, Unit Auxiliary Transformer and Auxiliary Transformer, including oil water separators; and
5) Foundations and bunds for cooling water external heat exchanger (radiators) and holding tank;

4.1.1.3 Substation Yard Foundations

1) Foundations for the landing gantries;
2) Foundations for the 275 kV disconnectors;
3) Foundations for two sets of three 275 kV Capacitive Voltage Transformers (CVTs);
4) Lightning and lighting masts foundations;
5) Foundations for diesel generators;

6) Cable ducts, cable pits, trenches and conduits (including suitably load-rated trench covers when crossing roadways). This includes telecommunication pits and conduits as per requirements; and

7) Substation earthing including main earth grid, risers, trench covers, and Vehicle Access Barriers (VABs).

4.1.2 Primary Infrastructure

The following primary plant is required to be installed and commissioned to allow the connection of the Davenport synchronous condensers to the network.

4.1.2.1 Substation Connection Works

Install all required droppers from existing line exits (former Northern Power Station generators no.1 and no. 2, now disconnected), including from the landing span line onto the disconnectors / surge arrestors.

4.1.2.2 Synchronous Condenser no.1 connection (Diameter C08)

1) Two new gantry towers plus cross beam;
2) 275 kV disconnector with two earth switches;
3) 275 kV post insulators;
4) Strung bus between new gantry and Diameter C08 gantry; and
5) Three 275 kV CVTs between disconnectors A6831 & A6830.

4.1.2.3 Synchronous Condenser no.2 connection (Diameter C07)

1) Two new gantries towers plus cross beam;
2) 275 kV disconnector with two earth switches;
3) 275 kV post insulators;
4) Strung bus between new gantry and Diameter C07 gantry; and
5) Three 275 kV CVTs between disconnectors A6837 & A6836.

4.1.3 Secondary System Infrastructure

The following secondary system equipment and modifications are required to be installed and commissioned to allow the connection of the Davenport synchronous condensers to the network:

4.1.3.1 Synchronous Condenser no.1 connection point protection

1) Decommission protection system of line exit for former (now disconnected) Northern Power Station generator no.1;
2) Install and commission new circuit breaker management relay for circuit breaker CB6562;

3) Install and commission new circuit breaker management relay for circuit breaker CB6561;

4) Modify Bungama line protection relay configurations to include circuit breaker fail function for circuit breaker CB6561; and

5) Connect and commission CT, CVT, tripping and status inputs between Davenport Control Building 1 & synchronous condenser no.1 Control room.

4.1.3.2 Synchronous Condenser no.2 connection point protection

1) Decommission protection system of line exit for former (now disconnected) Northern Power Station generator no.2;

2) Install and commission new circuit breaker management relay for circuit breaker CB6565;

3) Install and commission new circuit breaker management relay for circuit breaker CB6564;

4) Modify Mount Lock line protection relay configurations to include circuit breaker fail function for circuit breaker CB6564; and

5) Connect and commission CT, CVT, tripping and status inputs between Davenport Control Building 1 & Synchronous Condenser no.2 Control room.

4.1.3.3 Automation & SCADA

1) Connect all new relays in Control Building 1 to OpsNet switches for DNP over IP interface to RTU;

2) Install and commission gateway connections from synchronous condenser no.1 & synchronous condenser no.2 gateways into Control building 1 RTUs; and

3) Update Davenport HMI system to reflect alarms from synchronous condenser no.1 & synchronous condenser no.2 RTUs.

4.1.3.4 Telecommunications

1) Install and commission redundant fibre optic paths between synchronous condenser no.1, synchronous condenser no.2 and control building 1; and

2) Install and commission all new gateway switches.

4.1.3.5 Asset Performance

1) Synchronous condenser no.1 connection point CB, CT & CVT to be connected to Power System Performance Monitoring (PSPM) system; and

2) Synchronous condenser no.2 connection point CB, CT & CVT to be connected to PSPM.

4.1.3.6 Fire & Security

1) Install and commission the Fire and Security panel in synchronous condenser no.1 and synchronous condenser no.2 control rooms into Master unit.

4.1.3.7 Reactive Plant Control Scheme

Currently there are three 275 kV reactors installed on lines at the Davenport substation. A fourth reactor is going to be installed on the line exit in Diameter C02. The current reactor locations are as follows:

1) Brinkworth line exit;
2) Belalie line exit;
3) Mount Lock line exit; and
4) Mount Gunson South line exit (future)

The scope of the works for the Davenport will include the design and implementation of a control scheme to switch the reactors in and out of service based on the local voltage conditions and the output of the synchronous condenser units.

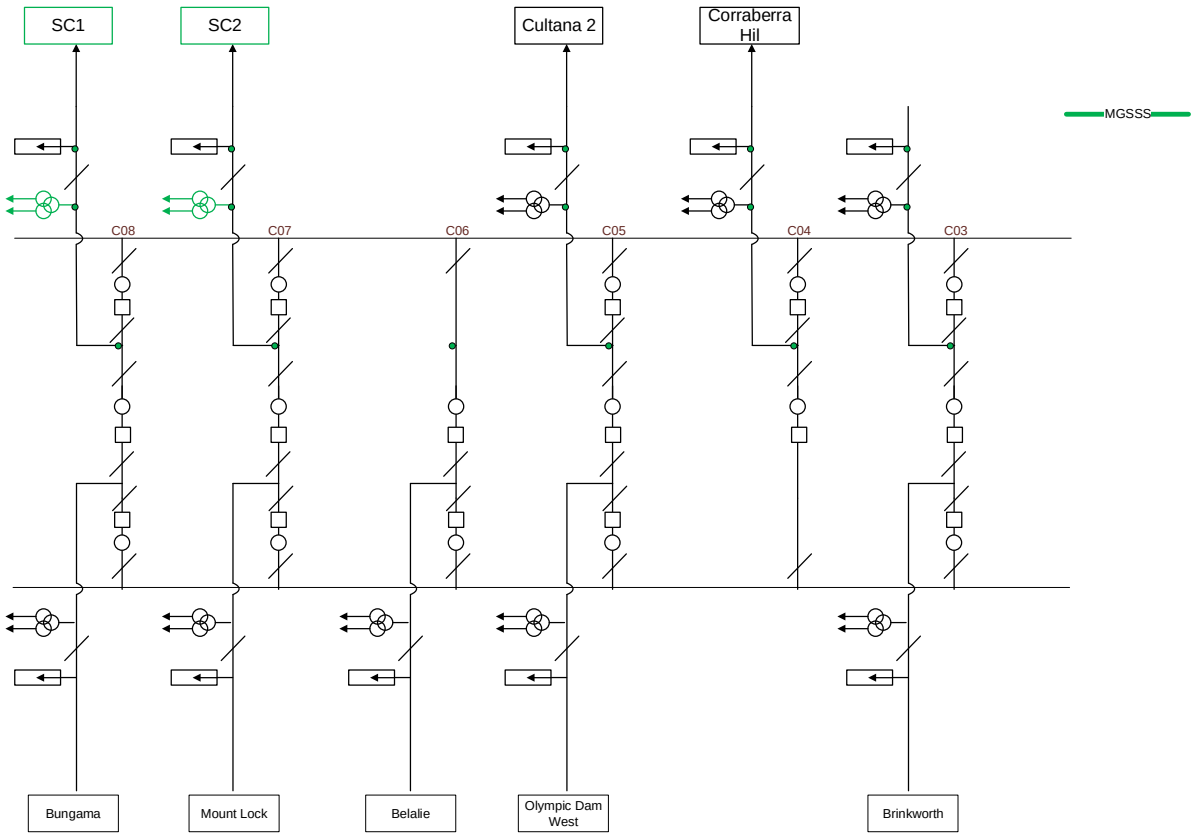
4.1.4 Interface with the Distribution Network Service Provider (DNSP)

The following works are required to be carried out by the DNSP:

1) Relocation of existing 33kV cable and pole-mount transformer (33kV / 400Vac);
2) Relocation of 33kV / 19 kV pole mount transformer;
3) Relocation of SWER lines,

Such that DNSP's equipment, currently located on the site where the new synchronous condensers yard is intended to be configured, will be relocated and thus, would allow the construction works for the synchronous condenser yard to proceed.

4.1.5 Davenport Simplified Single Line Diagram



4.2 Robertstown Substation

4.2.1 Civil Works

4.2.1.1 General Civil Works

The civil works will include the design, verification, certification and construction of the following:

4.2.1.1 Overall Civil Works

1) Bulk earthworks for the synchronous condenser yard;
2) Bulk earthworks for substation yard bench extension;
3) Substation site security fencing and gates (including temporary fencing as required);
4) Internal substation access roads;
5) Substation platform stormwater drainage and appropriate discharge point(s) that shall integrate into the peripheral site drainage of the overall development;
6) Integration of water drainage for the Robertstown substation extension in the overall Robertstown substation water drainage system;
7) Levee wall around new bench;
8) Lightning and lighting mast foundations;
9) Cable ducts, cable pits, trenches and conduits (including suitably load-rated trench covers when crossing roadways). This includes telecommunication pits and conduits required for the cabling requirements; and
10) Substation earthing including main earth grid, risers, trench covers, and Vehicle Access Barriers (VABs).

4.2.1.2 Synchronous Condenser Yard Foundations

1) Foundations for the synchronous condenser buildings;
2) Foundations for the synchronous condenser, flywheel and pony motor in the machine hall / annexures;
3) Foundations for other synchronous condensers and flywheels associated equipment in the machine hall and annexures;
4) Foundations and bund walls for the for the step up transformer, unit auxiliary transformer and auxiliary transformer, including oil water separators;
5) Foundations and bunds for heat exchangers (including holding tanks); and
6) Foundations for the diesel generator.

4.2.1.3 Substation Yard Foundations

1) Foundation for a new control building to be located within the Robertstown substation extension;
2) Foundation for new AC changeover amenities building;

3) Foundations for six new 275 kV circuit breakers;
4) Foundations for six sets of 275 kV current transformers (CTs);
5) Foundations for six sets of three 275 kV CVTs;
6) Foundations for fourteen 275 kV disconnectors and earth switches;
7) Foundations for 275 kV bus support post insulators; and
8) Foundations for six 275 kV gantries.

4.2.2 Primary Infrastructure

The following primary plant is required to be installed and commissioned to allow the connection of the Robertstown synchronous condensers to the network.

4.2.2.1 Substation Extension Works

1) Installation of 275 kV tubular busbar and bus supports to extend configuration to include:
    a. New 275 kV disconnector in bus section location of the North Bus;
    b. New 275 kV disconnector in bus section location of the South Bus;
    c. Three phase 275 kV CVTs on the North Bus;
    d. Three phase 275 kV CVTs on the South Bus;
    e. Replacement of CVTs on the Para line exits (diameter C04);
    f. Replacement of 275 kV disconnector A6924; and
    g. Installation of new surge arrestors on the Para line exit.
2) Modification of 275 kV North Bus connection to Transformer 1 to include the following:
    a. Replacement of 275 kV disconnector and earth switch (A66003) with new unit in new position;
    b. Installation of 275 kV circuit breaker;
    c. Installation of three phase 275 kV CT; and
    d. Installation of single phase 275 kV CVT.
3) Modification of 275 kV South Bus connection to Transformer 2 to include the following:
    a. Replacement of 275 kV disconnector and earth switch A6927 with new unit in new position;
    b. Installation of 275 kV circuit breaker;
    c. Installation of three phase current transformers; and
    d. Installation of single phase capacitive voltage transformer.

4.2.2.2 Synchronous Condenser no.1 (Diameter C07)

1) Three new gantries and strung bus to create diameter C07;
2) 275 kV bus disconnector Q11 with one earth switch;
3) Bus disconnector Q21 with one earth switch;
4) Three phase CT in Q20;
5) Circuit breaker Q20;
6) Coupler disconnector Q22 with one earth switch;
7) Three phase CVTs;
8) Line disconnector Q23 with two earth switches;
9) Coupler disconnector Q31 with one earth switch;
10) Three phase CT Q30;
11) Circuit breaker Q30; and
12) Coupler disconnector Q32 with one earth switch.

4.2.2.3 Synchronous Condenser no.2

1) Three new gantries and strung bus to create diameter C05;
2) 275 kV bus disconnector Q11 with one earth switch;
3) Bus disconnector Q21 with one earth switch;
4) Three phase CT (Q20);
5) Circuit breaker Q20;
6) Coupler disconnector Q22 with one earth switch;
7) Three phase CVTs;
8) Line disconnector Q23 with two earth switches;
9) Coupler disconnector Q31 with one earth switch;
10) Three phase CT (Q30);
11) Circuit breaker Q30; and
12) Coupler disconnector Q32 with one earth switch.

4.2.3 Secondary Infrastructure

The following secondary system equipment and modifications are required to be installed and commissioned to allow the connection of the Robertstown synchronous condensers to the network:

4.2.3.1 Substation Protection Works

1) 275 kV North Bus Right
    a. Installation and commissioning of new low impedance Set 1 protection (GE B30); and

b. Installation and commissioning of new low impedance Set 1 protection (Micom P746).

2) 275 kV South Bus Right

a. Installation and commissioning of new low impedance Set 1 protection (GE B30); and

b. Installation and commissioning of new low impedance Set 1 protection (Micom P746).

3) 275 kV Transformer 1

a. Installation and commissioning of new CB management panel for new circuit breaker;

b. Modify and commission existing transformer differential protection to remove previous CT connections and install newly installed CT; and

c. CVT to be incorporated into Sync Check.

4) 275 kV Transformer 2

a. Installation and commissioning new management relay panel;

b. Modify and commission existing transformer differential protection to remove previous CT connections and install newly installed CT; and

c. CVT to be incorporated into Sync Check.

4.2.3.2 Synchronous Condenser no.1 connection protection (Diameter C07)

1) Q20 CB management relay;
2) Q30 CB management relay;
3) Bay control units (BCU) for Q20;
4) Bay control units (BCU) for Q30; and
5) Interface of CT, CVT, tripping and status to synchronous condenser no.1 control room.

4.2.3.3 Synchronous Condenser no.2 connection protection (Diameter C05)

1) Q20 CB management relay;
2) Q30 CB management relay;
3) Bay control units (BCU) for Q20;
4) Bay control units (BCU) for Q30; and
5) Interface of CT, CVT, tripping and status to synchronous condenser no.2 control room.

4.2.3.4 Automation and SCADA

1) HMI work station;
2) SEL 2240 Miscellaneous BCU;
3) Tekron clock;

4) Invertor;

5) Connect all new relays in Control Building 3 to OpsNet switches for DNP over IP interface to RTU; and

6) Install and commission gateway connections from synchronous condenser no.1 & synchronous condenser no.2 gateways into Control building 3 and control building 1 RTUs.

4.2.3.5 Telecommunications

1) Two conduit routes (fibre) between +1 building and new control building;

2) OpsNet cubicle with 4 x MPS Switches;

3) 2 x DC/DC converters;

4) 2 x ATA Phone (OPAX & PSTN); and

5) 1 x WAP.

4.2.3.6 Asset Performance

1) Install new PSPM with adequate inputs for all the required plant in the new diameters C01, C02, C05, C06 & C07.

4.2.3.7 Fire & Security

1) Install and commission the Fire and Security panel in Synchronous condenser no.1 and Synchronous condenser no.2 control rooms into Master unit.

4.2.4 Interface with DNSP

The following works are required to be carried out by the DNSP

1) Relocation of existing 33kV cable and pole-mount transformer (33kV / 400Vac);

2) Relocation of 33kV / 19 kV pole mount transformer;

3) Relocation of SWER lines,

Such that DNSP's equipment, currently located on the site where the new synchronous condenser yard is intended to be configured, will be relocated and thus, would allow the construction works for the synchronous condenser yard to proceed.

4.2.5 Robertstown Simplified Single Line Diagram