CITIPOWER	ELECTRICITY NETWORKS Asset Strategy and Performance Functional Scope	Powercor AUSTRALIA

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Version	Date	Changes	Responsible Officer
1.0	31.03.2016	Original	A. Satkunalingam
1.1	19.04.2016	Updated gas switch details for balancing units	A. Satkunalingam
1.2	06.01.2017	Updated based on GSB and WND installations	A. Satkunalingam

1 Project overview

This project scope covers the migration of the Maryborough zone substation (**MRO**) system to a resonant earthed network. Migration to a resonant network requires the installation and operation of a ground fault neutraliser (**GFN**). This changes the electrical operating characteristics of a zone substation and its distribution network as follows:

- full voltage displacement occurs on the system for operation of the GFN;
- this significantly stresses equipment on the system and may lead to failure;
- this equipment has been identified and included in this scope for replacement as part of the GFN installation; and
- other limitations will dictate part of the operational protocols that will be developed by Electricity Networks.

The GFN provides potential benefits to single-phase-to-ground faults on the 22kV three phase system. It provides no benefit on the following:

- the 12.7kV Single Wire Return System (**SWER**);
- the 66kV sub-transmission system; and
- the low voltage (**LV**) system.

1.1 Background

The Victorian Government has introduced changes to the Bushfire Mitigation Regulations that require distribution businesses with high voltage (**HV**) overhead assets in high bushfire consequence areas to meet new performance standards for detection and limiting of arc fault energy. These standards can only be achieved using rapid earth fault current limiters (**REFCLs**).

A REFCL is a network protection device, normally installed in zone substations that significantly reduce the arc fault energy generated during a phase to ground fault. The reduction in arc fault energy can be so effective that earth fault fire ignition on 22kV three phase networks is almost eliminated.

The Bushfire Mitigation Regulations mandate that REFCLs must provide the required capacity—required capacity means, in the event of a phase-to-ground fault on a polyphase electric line, the ability:

- to reduce the voltage on the faulted conductor in relation to the station earth when measured at the corresponding zone substation for high impedance faults to 250 volts within 2 seconds; and
- to reduce the voltage on the faulted conductor in relation to the station earth when measured at the corresponding zone substation for low impedance faults to:
  - 1900 volts within 85 milliseconds; and
  - 750 volts within 500 milliseconds; and
  - 250 volts within 2 seconds; and
- during diagnostic tests for high impedance faults, to limit:
  - fault current to 0.5 amps or less; and
  - the thermal energy on the electric line to a maximum I^2t value of 0.10;

  where:

- high impedance faults means a resistance value in ohms that is equal to twice the nominal phase-to-ground network voltage in volts;
- I^2t means a measure of the thermal energy associated with the current flow, where I is the current flow in amps and t is the duration of current flow in seconds;

- low impedance faults means a resistance value in ohms that is equal to the nominal phase-to-ground network voltage in volts divided by 31.75; and
- polyphase electric line means an electric line comprised of more than one phase of electricity with a nominal voltage between 1 kV and 22 kV.

1.2 Maryborough zone substation

MRO zone substation is a banked station that supplies the township of Maryborough and extending into surrounding rural areas. MRO ZSS 22kV comprises of two 13MVA 66/22kV transformers supplying 6 22kV feeders.

Table 1 MRO: existing characteristics (zone substation)

Zone substation	Volume
Feeders	6
Zone substation transformers	2
22kV buses	2
Capacitor banks	1
Station service transformers	1
22kV circuit breakers (switching configuration)	6 (banked)

Table 2 MRO: existing characteristics (network)

Network	Volume
Total route length (km)	946
Underground cable length (km)	4
Overhead line length (km)	942
Underground network (%)	0.4
Overhead single phase (km)	423
Estimated network capacitance (A)	74
Distribution transformers	1,443
HV regulator sites	4
Fuses	1,544
ACRs	9

Network	Volume
Surge arrestor sites	1,665
HV customers	-

2 ZSS requirements

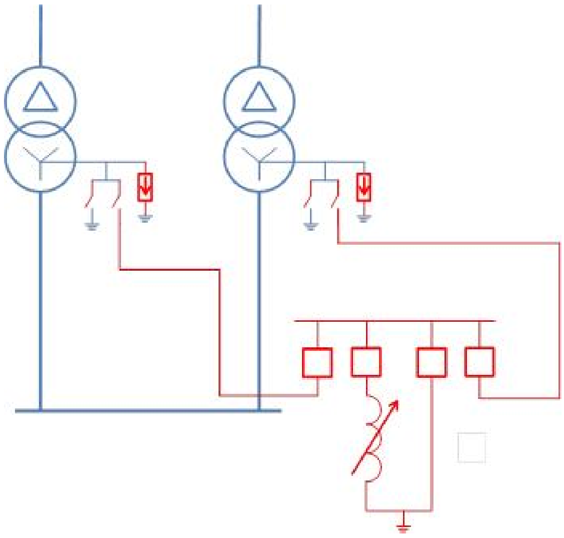
This functional scope sets out the CDN zone substation requirements, including the following:

- Establish Arc Suppression Coil (ASC) bunds
- Installation of one (1) Swedish Neutral GFN Arc Suppression Coils
- Modification of the 66/22kV transformer earthing arrangement
  - Installation of Neutral Bus System
    - Transformer neutral CB's
    - Ground terminations
    - ASC Terminations
    - Neutral VT Installation
- Upgrade station service supply transformers with one (1) new 500kVA kiosk transformer
- Upgrade of the station service supply cabling and installation of new AC distribution board
- Replace ALL substation surge arrestors with new 22kV continuous voltage units for resonant network compatibility and 10hr 24kV TOV capability
- A GE F35 relay shall be installed and configured as the X MEF and Neutral Bus Management relay. The relay will execute and manage the following functions;
  - Master Earth Fault relay for NER/direct earth in service applications
  - Neutral Voltage Supervision
  - Neutral Bus CB Management
- Install a SEL-451 Station Earth Fault Management relay to perform the automated control of the GFN. The relay will manage the following functions;
  - Operating mode selection
  - GFN remote controls
  - Automate fault detection handling
  - Request fault confirmations consistent with operating mode
  - Trip faulted zones consistent with operating mode
  - Bypass ASC
  - Provide local controls and indications
- Install and Commission one (1) GFN control and one (1) RCC inverter cubicles
- Modification of existing Capacitor Bank
  - Remove HV earth from star point
  - Install new CB Management relay incorporating overcurrent and earth fault functions
  - Install new station VAR controller
- Install new Elspec Power Quality Meter.

2.1 Primary plant requirements

The works associated with the installation of the MRO ASC arrangement is summarised in the following single line diagrams.

Figure 1 MRO single line diagram



2.1.1 Ground bypass isolators

For each transformer neutral earthing, install a ground by pass isolators at the transformer. This is required in the case that the neutral bus is to be taken out of service, transformer neutrals can be earthed by closing these ground by pass isolators.

2.1.2 Arc suppression coil

Install Swedish Neutral - Ground Fault Neutraliser's Arc Suppression Coil (ASC) component. The ARC suppression coil is a paper wound copper coil wrapped around a solid iron core and immersed in oil. This arc suppression coil is of fixed reluctance but contains an array of capacitors in parallel that are switch as part of the tuning process of the coil. The coil also features an LV winding for coupling of these capacitors and the Residual Current Compensator.

Primary neutral and earth connections are via elbows.

As oil filled device, it shall be installed in a bunded area in accordance with current standards. The total volume of oil will be made available once the coil size has been confirmed.

The GFN ASC shall be installed in the north western corner of the substation:

- install Ground Fault Neutraliser comprising of 200A ASC and residual current compensation module with maximum available tuning steps onto the provided pad mount within a newly established bunded area;
- the footing of the ASC shall reside on the installed 150mm steel beams fixed to the concrete pad; and
- install cable connections to and from the Neutral System.

2.1.3 Zone substation surge arrestors

The operating principle of the GFN uses a tuned reactance to choke fault current in the event of a single-phase-to-ground fault. As a result, displacement of the line-to-ground voltage occurs in the healthy phases. Whilst line-to-line voltages remain at 22kV, the line-to-ground voltage rises to 22kV, phase-to-ground, on the two healthy phase's subsequently stressing substation and distribution equipment. In the case of surge diverters, this displacement cannot be tolerated and as such the diverters require replacement.

To accommodate the GFN installation:

- replace all sub-standard zone substation surge arresters with a station class 22kV continuous voltage arrestor; and
- install station class 19kV surge arresters across the transformer neutrals.

2.1.4 Zone substation capacitor bank

The existing No.1 22kV Capacitor Bank is connected in grounded star. The bottom modules of the stack reside on a 22kV insulated structure. The existing No.1 22kV Capacitor bank at MRO is an externally fused capacitor bank and hence does not require neutral balance protection.

To facilitate GFN installation, the earth must be removed from this Capacitor Bank:

- the neutral structure shall be modified such that the earth connection be removed and the neutral point floating with a continuous insulation rating of not less than 13kV;
- install station class 19kV surge arrestor between the floating star-point and earth; and
- remove the Cap Bank Neutral CTs.

2.1.5 Neutral system arrangement

A new kiosk type ground mounted Neutral Bus system shall be installed with the ASC. The neutral bus system allows for integration of the ASC onto the transformer neutral.

The purpose of this arrangement is to provide a simple switching configuration that offers the following combinations within one kit:

- solid grounding; and
- ASC in service (Solid Ground CB Open).

Neutral Bus

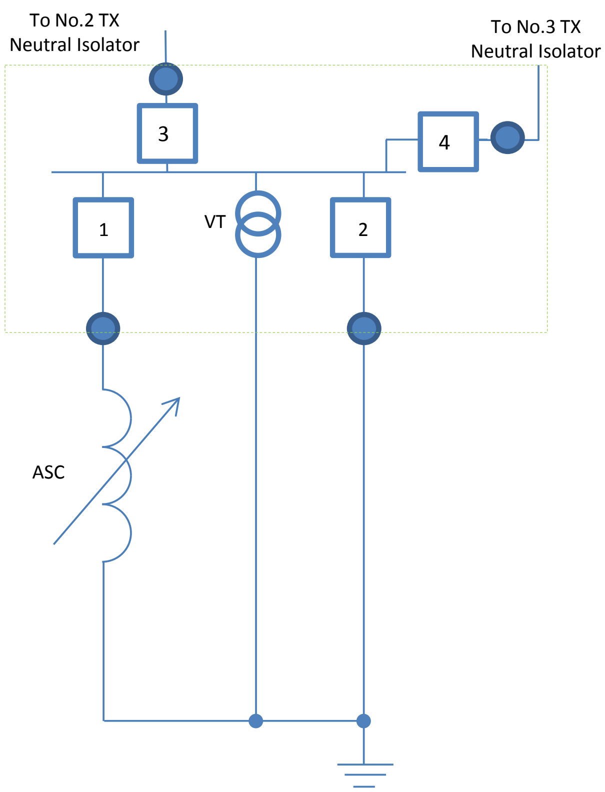
The connection to the Neutral Bus module shall be via elbow connections. Four (4) elbows are required per module for:

- transformer No.1 Neutral connection;
- transformer No.2 Neutral connection;
- ASC connection; and
- bus tie connection.

Neutral Voltage Transformer

A neutral VT shall be included in each of the Neutral Bus modules. The neutral VT shall be 0.5M 1P at 15VA.

Figure 2 Proposed MRO neutral system single line diagram



2.1.6 Transformer Earthing

The two 66/22kV, 10/13 MVA transformers in service at MRO are delta/star connected with the neutral of the star windings solidly earthed.

The neutral earthing arrangement shall be modified to incorporate the new earthing arrangement (refer SLD) with connection to the ASC. The transformer neutrals from each transformer shall be extended using a HV insulted single phase cable installed underground from the existing transformer neutral earthing point to the HV CB (via the elbow connections) on the Neutral Bus modules (RMU).

2.1.7 22kV bus VT

Existing 22kV bus VT is a Vee connected VT (phase to phase voltages from VT red and blue windings). Replace existing VT with a VT with the following specification (SAP ID – 381684):

- 3-Phase 5 Limb construction;
- Frequency – 50Hz;
- Ratio - 22,000/110/110V;
- Connection - STAR/STAR/STAR;
- Vector Group - YNyn0yn0;
- Output - 100VA per phase per secondary winding; and
- Accuracy class - CLASS 0.5M1P per secondary winding.

2.1.8 Neutral Surge Diverter

As the 66/22kV Transformers at MRO are outdoors, neutral surge diverters are to be installed.

Install and connect a Station Class 19kV surge diverter between the transformer neutral bus and the substation earth grid. The surge diverters should be connected as close to the transformer neutrals as possible.

2.2 Civil works requirement

For neutral systems:

- install concrete foundation pad for neutral system module;
- install neutral cable conduit, control cable conduit and provision for solid earth grid connections;
- install neutral cable conduits from transformers to neutral bus; and
- install conduits for secondary circuits.

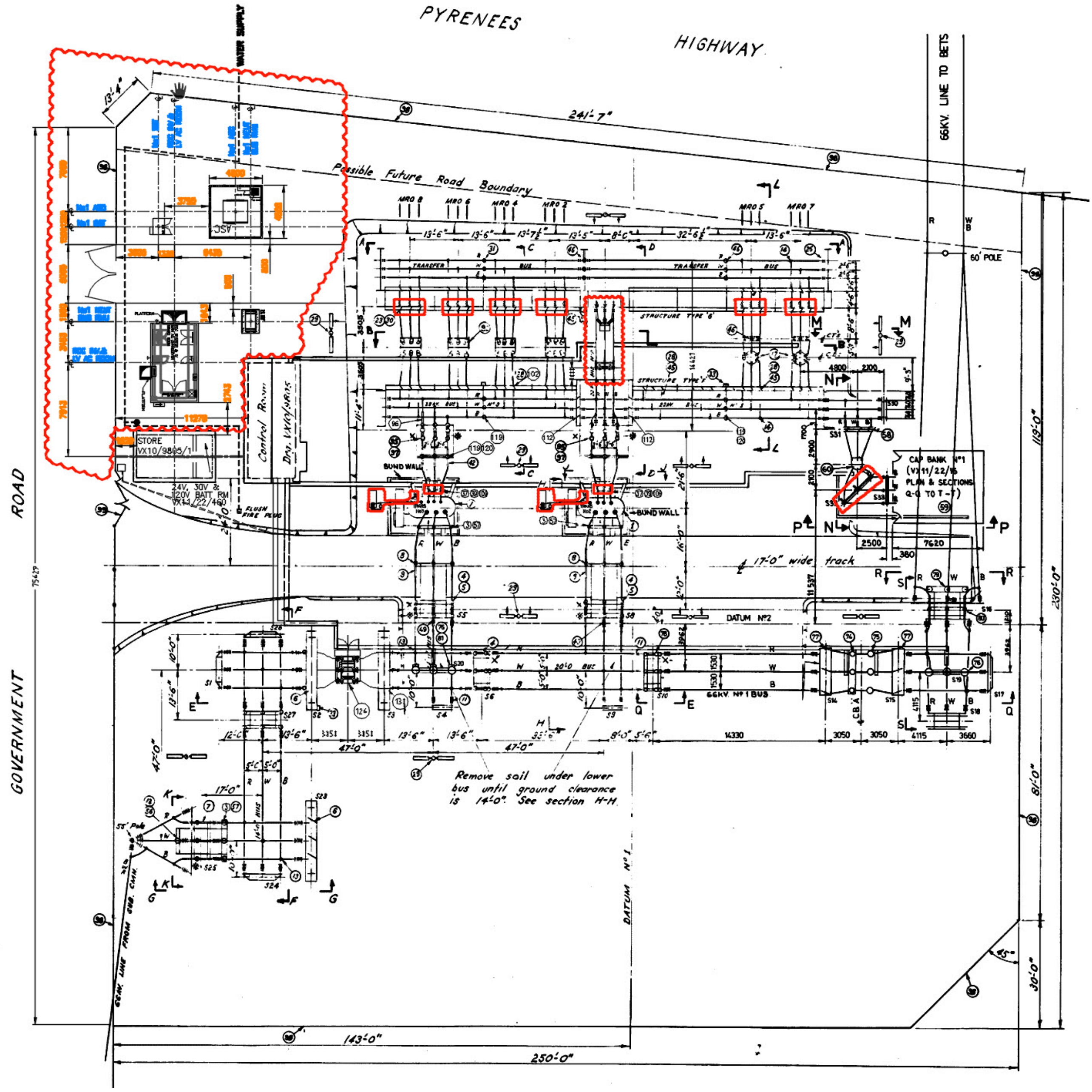
For ASCs:

- install neutral cable conduit, control cable conduits and solid earth grid connections;
- pour concrete foundation;
- install steel beam, 150mm high at a width designed to accommodate the placement of the GFN Arc Suppression coil; and
- install bunding to EPA requirements.

For station service supplies:

- review station service transformer foundations and enclosure for upgrade to 500kVA. Note the existing station service is 25kVA.

Figure 3 Proposed MRO substation layout



2.3 Secondary works

The following outlines the Protection and Control requirements.

All secondary drawings shall be in the wiring schematic format consistent with the existing suite of drawings for the station.

NOTE: All works specified below is based on the MRO relay replacement project being completed prior to this REFCL installation.

2.3.1 Protection Schemes

Panel 7 – 66kV CB MGT & CB Fail

Install

- One (1) new SEL-351S CB management relay (66kV CB A)

Design notes

- Both 66kV CB management relays (CBA and CB B) shall be reconfigured to provide external protection trip initiations via IEC61850 GOOSE
- This is required to enable GOOSE tripping from the GFN controller to the next zone up (failure of the feeder CB operation will enable tripping of the next zone feeders)

Panel 9 – 66kV Metering

Retire

- All metering equipment and associated wiring

Install

- Blanking plates

Design notes

- 66kV Metering information will be available on 66kV CB management relays on panel 7

Panel 11 – No.1 Bus Feeder Protection Relays

Retire

- Existing 2 x SEL-351S feeder management relays and associated wiring

Install

- Two (2) new SEL-351S feeder management relay (MRO5 & MRO7)
- Tekron TCG-01 GPS Clock

Design notes

- The existing SEL351S relays were installed in 2006 cannot be upgraded to do IEC 61850 (firmware version Z006 and does not have an Ethernet Port)

SEL-351S Feeder Protection Configuration:

- Relays shall be reconfigured with directional control capability for all phase, neutral and earth fault elements
- Relays shall be reconfigured to provide external protection trip initiations via IEC61850 GOOSE
  - These GOOSE initiations shall drive auto reclose functionality direct to lockout through the internal 79DTL function

- The CB fail functionality of the feeder CBs will be provided by the GFN controller. In this case the 66kV CB management relays will be tripped by GOOSE trip initiations from the GFN controller.
- The 22kV feeders contain only two protection CT's for feeder and transformer/bus differential protection. The transformer/bus differential protection CT's shall remain undisturbed.
- 22kV Feeder CT contributions are required by the GFN zero sequence bus admittance calculations. To facilitate the GFN connection, install an extra set of neutral links on feeder link rack to permit the installation of the I0 connection off to the GFN controller

Panel 13 – No.1 Cap Bank Protection, Metering & Control & MEF and BUEF Relay

Install

- (N) GE F35 X MEF and Neutral Bus Management relay

Design notes:

- GE F35 X MEF and Neutral Bus Management relay shall provide the following functions:
  - Master Earth Fault relay for NER/direct earth in service applications
  - Neutral Voltage Supervision
  - Neutral CB Management
- Existing cap bank is an externally fused and hence does not have neutral balance protection.
- Remove the cap bank No.1 neutral current contribution from the MEF and BUEF protection circuit to accommodate the removal of the No.1 Cap bank earth connection from the neutral star point.

Panel 17 – New Station Earth Fault Management

Install

- (N) SEL-451 Station Earth Fault Management relay

Design notes:

- Station Earth Fault Management relay is require to perform the automated control of the GFN installed at the substation. This relay will manage the following functions:
  - operating mode selection;
  - GFN remote controls;
  - automate fault detection handling;
  - request fault confirmations consistent with operating mode;
  - trip faulted zones consistent with operating mode;
  - bypass ASC; and
  - provide local controls and indications.

2.3.2 Ground Fault Neutraliser

Control Unit

The GFN control unit is a single cubicle comprising of:

- GFN Master Control module
- GFN Slave Control Module

- Windows Based PC utilising proprietary NM Term software
- All VT and feeder I0 CT terminations
- All trip link outputs
- RCC Inverter and ASC Interface
- Panel Meters

MRO zone substation will only require one (1) GFN controller as it will not require a split bus operation.

Powercor will request through their specification process that the control unit be constructed within a 850mm wide cubicle. Each cubicle will contain an interface controller in the form of a SEL-2440 DPAC control unit in the top 2U of this cabinet. This control unit will be used to interface controls to the Station Earth Fault Management relay.

The GFN cubicle shall be in panel 16 position (refer to Appendix C for proposed location of the GFN control cubicle).

VT Supplies (R,W,B & VN) are required from bus into the GFN controller along with Feeder and Transformer neutral summation (IN) circuits.

Inverter

The Residual Current Compensation technique used by the GFN requires an Inverter to inject current into the ASC via an auxiliary winding. The inverter must be sized to displace the full capacitive current drawn by the system and as a result requires significant power.

The performance specification discussed earlier calls for a 0.5A fault current sensitivity. GFN sensitivity is determined by two main factors;

- system damping; and
- capacitive dissymmetry.

The size and future growth of MRO does not suggest any issues in meeting this threshold with one ASC.

The inverter requirement is also quite large as it must have the power to counter balance the system damping and capacitance when in operation. Inverters in the order of 300-400kVA is expected.

The inverters shall be installed in a separate air conditioned hut in the switchyard. Inverter AC Supplies to be supplied off the new station service transformer.

2.3.3 VT supplies

Auxiliary transformer for GFN

VT supplies from the new 22kV Bus VT is required to the GFN control unit. For earth fault detection, an open delta (UN) input is required from the 22kV bus VT at 110V secondary. To achieve this, Swedish Neutral has provided an auxiliary transformer in their GFN control cubicle.

2.3.4 Protection settings

A protection review shall be undertaken by Network Protection and Control of all schemes within MRO zone substation with particular reference to earth fault schemes on the 22kV network:

- SEL-351S relays will have configuration changes to introduce:
  - directional SEF functionality;
  - GOOSE (via GFN) tripping capability;
  - auto Reclose integration of GFN initiated trips;
  - GOOSE message isolation function;

- the station MEF and BUEF schemes shall be reviewed for GFN integration (there is no REF protection at MRO);
- an application for backup Voltage Displacement shall be considered;
- transformer protection settings to be reviewed with the new larger size station transformer in service which is in the transformer protection zone; and
- refer to Appendix for a marked-up DPS.

2.3.5 Protection relay configurations

Powercor Network Protection and Control will make standard relay configuration files available to the Service Provider where appropriate. Given the nature of this project, the service provider must expect that this project will have non-standard requirements.

2.3.6 Metering requirements

Panel 9 – 66kV Metering

Retire

- 66kV metering and control equipment and associated wiring

Design notes

- 66kV metering will be available on panel 7 via the 66kV CB management relays

Panel 10 – Summation Metering and Power Measure System

Retire

- Existing ION7600 PQM and all associated wiring
- Transformer metering equipment and all associated wiring

Install

- One (1) new ION7650 PQM
- Two (2) new ION6200 PQM
- ELSPEC Power Quality Meter and Data recorder

Design Notes

- The PQM and transformer metering need to be retired to make space for the ELSPEC meter.

ELSPEC Power Quality Meter

- This recorder is capable of recording 16 analogue and 32 digital channels of data at a sampling rate of 1,000 samples per second. 12 months of data can be captured and stored internally using a patented algorithm.
- The ELSPEC shall be installed to capture bus voltage, neutral voltage and bus incomer currents (ie transformer currents). The purpose of this recorder is to aid with GFN commissioning and long term monitoring.
- This cubicle contains the old PQM meter.
- Connectivity to the ELSPEC meter to be fibre 100BASE-FX Ethernet to a new RS 2100 switch in Panel 7.

ION meter

- Transformer metering will be available via the new ION6200 panel meters.
- These ION6200 panel meters shall be connected to the PQM ION7650 via RS485 connection (Modbus protocol) using the COM 2 port.

- The PQM should be connected to the RS2100 SUBLAN switch for both SCADA and PQM server (Given that the DNP3 conversion at MRO is schedule for 2016).

2.3.7 Control and monitoring requirements

Remote Control and Monitoring of new:

- SEL-351S Feeder Protection Relay Configurations
- X MEF & Neutral System CB Management Relay UR F35
- GFN Controller
- ELSPEC Power Quality recorder
- 66kV CB 'A' and CB 'B' CB Management and CB Fail Relay

Shall be via DNP 3.0 with DNP Maps provided to the SCADA group and produced by the service provider in conjunction with Network Protection and Control.

Powercor SCADA group are responsible for developing a suite of ENMAC control pages in conjunction with the Network Operations group and Network Protection and Control.

2.3.8 Communications Requirements

Ethernet Connectivity

All communications shall be over 100 BASE-FX (optic fibre) Ethernet back to the zone substation Sub-LAN RSG-2100 Ethernet switches. Preferably, devices maintain duplicated Ethernet connectivity either through an internally "switched" architecture or a preferred and failover arrangement.

Tripping from the GFN to the feeder CB's will be over IEC 61850 via an interface module built into the GFN control cubicle. For this reason, the architecture for Ethernet communications shall change to eliminate "loops" that emanate from the sub-LAN switch for devices that are involved in this scheme.

Given the proximity of the devices to be connected, two (2) new RuggedCom RSG-2100 switches (location specified in the panel layout drawing attached in Appendix) are adequate at MRO:

- install Gigabit backbone connection between the two new Ethernet switches;
- install fibre Ethernet links from the SEL-351S Feeder Protection relays, Cap Bank protection relay, 66kV CB management relays, Station EF relay, ELSPEC PQM, Station PQM, GFN DPAC to each Ethernet switch;
- install fibre connections from GFN Interface controller (SEL-2440):
  - all Port 5A connections to MRO-RSG2100-01;
  - all Port 5B connections to MRO-RSG2100-02;
  - ensure relay configurations modified to Port Failover configuration; and
  - ensure Sub-LAN switch architecture configured to support fail over scenario's.

A suggested Ethernet connection diagram is included in Appendix.

Engineering Access

Powercor SCADA shall ensure remote engineering access is available to select members of the Network Protection and Control group. Remote access is required to all sub-LAN connected devices including protection relays, data recorders and GFN controller.

Time Stamping

The existing Tekron TCG-01 GPS Clock is to be used for time stamping all equipment. All NTP capable equipment shall synchronise with the WND GPS NTP server. All non NTP capable equipment is to be connected to the MRO GPS IRIG-b loop.

2.3.9 AC supplies

The existing 25 KVA station service supply transformer is located in the switchyard and is supplied of the 22kV bus. The size of this station service transformer will not be adequate for the RCC inverter used to drive faulted phase voltage to zero via the Arc Suppression Coil.

This station service transformer shall be replaced with a 500kVA kiosk type station service transformer with LV mains upgraded accordingly (subject to space constraints).

Since the station service transformer is supplied off the 22kV bus, there is no need for a second station service transformer or an AC changeover scheme.

The AC Supplies must ensure capacity and reliability requirements are fulfilled for a single ARC Suppression Coil.

Install current limiting fuses to be installed on distribution AC board supplies.

Upgrade existing station AC board and incoming mains such that they are compliant with existing standards.

Install AC supplies for the GFN inverter to meet its specifications.

2.3.10 DC supplies

The battery capacities shall be verified as being of adequate capacity to supply the station standing load and any CB operations that could occur within a 10 hour period following loss of AC Station Service supplies.

Documentation must be provided that demonstrates the battery amp-hour rating chosen has been sized for the load and the duty of the load. Calculations and appropriate documentation must be provided to demonstrate compliance with IEEE – 485 “IEEE Recommended Practices for Sizing Lead Acid Batteries for Stationary Applications”.

The existing 24V, 30V and 120V chargers are located in a separate building to the control room.

All exposed ‘clothes line’ style DC buses in the control room shall be retired as part of the MRO relay replacement project in 2016.

2.3.11 Station design

As a minimum the secondary design documentation shall include:

- 22kV Station Schematic Diagram
- Protection, Control, Instrumentation and Alarm data schedules
- Control room layout and elevation of cubicles
- Cubicle Layouts
- Wiring schematics/diagrams for individual protection, control and metering schemes
- DC supply schematics
- Remote control equipment and associated data schedules
- Labelling for cubicles and all slide link terminals
- Manufacturer and interface drawings for the Ground Fault Neutraliser equipment.

The latest modular design concepts shall be used as far as practical for this project.

2.3.12 Powercor control centre SCADA works

A new series of Control System Pages shall be created for the GFN interface. Consultation between SCADA, Operations and Network Protection and Control is required to establish these pages.

2.3.13 Fibre optic cable

Fibre optic patch leads are required for Zone Substation Sub-LAN Ethernet communications.

These optic fibres shall be of OM1 62.5/125um type.

2.3.14 Radio

No radio communications are required.

2.3.15 Building and property considerations

Yard lighting

Switch yard lighting shall be reviewed to ensure adequate coverage of the ASC, Neutral System.

Fire suppression

The ASC winding is immersed in oil. A review of its design and the amount of contained oil is required to determine if any fire suppression assets are required.

3 22 kV distribution feeder requirements

3.1 Surge diverters and insulation limitations

The operating principle of the GFN uses a tuned reactance to choke fault current in the event of a single-phase-to-ground fault. As a result, displacement of the line-to-ground voltage occurs in the healthy phases. Whilst line-to-line voltages remain at 22kV, the line-to-ground voltage rises to 22kV, phase-to-ground, on the two healthy phase's subsequently stressing substation and distribution equipment. In the case of surge diverters, this displacement cannot be tolerated and as such the diverters require replacement.

To accommodate the GFN installation:

- replace approximately 2,182 surge diverters across the 22kV three phase and single phase system. This covers all feeders ex MRO ZSS;
- surge arrestors beyond inter-station open points shall also be upgraded to permit transfer of loads with the GFN in service; and
- the replacement diverters should be of 22kV continuous rating with a 10 hour 24kV TOV rating.

CitiPower and Powercor standard surge diverters are the ABB MWK 20 and POLIM D 20 arresters. These do not meet the overvoltage requirement needed for use with a GFN and therefore the higher rated arresters are required.

These surge diverters will be a new standard, applicable to distribution systems with a GFN installed.

3.2 Distribution transformers

Operation of the GFN displaces the neutral voltage of the entire 22kV system from the bus to the outer extremities of the feeders. This is different from an NER arrangement, when displacement is at its highest for a fault on the 22kV bus, and decreases for faults occurring down the feeders.

During GFN commissioning, voltage offset testing will simulate the voltage displacement that will occur for a single-phase-to-ground fault (22kV phase-to-ground).

1. Some distribution transformers may not be in a condition to withstand the overvoltage and will subsequently fail during the voltage offset testing
2. Some distribution transformers may fail following repeated subjection to sustained over-voltages caused post commissioning due to normal operation of the GFN

At this time, experience from network resilience (voltage stress) testing at GSB and WND does not support a proactive replacement of any distribution transformers.

3.3 Line insulators

As is the case above for distribution transformers, line insulators are also susceptible to premature failure caused by the repetitive over-voltage stresses.

Similar to Distribution Transformers, at this time, experience from the network resilience testing does not support a proactive replacement of any line insulators.

3.4 Line regulators

Single phase open-delta-connected Cooper regulators displace the system neutral voltage by regulating line-line voltages on two phases as opposed to three.

Closed-delta independent regulator control schemes tap each regulator independently, a similar displacement to the neutral voltage occurs, as per the open-delta mode.

All regulator works shall be compliant with current CitiPower and Powercor standards for 22kV regulators.

The MRO 22kV distribution network contains four 22kV regulating systems.

Table 3 MRO regulating systems

Feeder	Name	Manufacturer	Phasing	Issue
MRO5	Moonambel P182	N/A	3 phase	None
MRO5	Dunolly P133 & 133A	Cooper CL6B	2 phase	Open delta w/ independent controls
MRO7	Tarnagulla P150	Cooper CL6A	3 x 1 phase	Independent controls
MRO5	Landsborough P210	Cooper CL6B	2 phase	Open delta w/ independent controls

3.4.1 Moonambel P182

Moonambel P182 is installed in an acceptable configuration. A condition assessment is required to satisfy the three minute 22kV TOV requirement.

3.4.2 Dunolly P133 & 133A

Dunolly P133 &133A is a pole mounted regulator (two units reg across two poles) and connected in open delta. Existing CL6 control schemes control each regulator separately.

This regulator scheme shall have a third phase installed and be reconfigured as a closed delta system.

The controls shall be updated to a CL7 control unit such that:

- all units regulate and tap together in a master follower style scheme;
  - for ground mount option, a three phase CL7 module shall be employed;
  - for “adjacent pole option”, single phase CL7 running communicating over fibre optic can be used;
- each tank tap position is monitored and fed back into an out-of-step control circuit;
  - out-of-step logic shall lock out automatic control within 90 seconds of detection; and
- all alarms and controls shall be integrated into SCADA.

3.4.3 Tarnagulla P150

Tarnagulla P150 is a Cooper regulator with three single phase 100A regs with independent controls. The existing CL6 control schemes are installed on each phase and as such are controlled separately.

The controls shall be updated to a CL7 control unit such that:

- all units regulate and tap together in a master follower style scheme;
- each tank tap position is monitored and fed back into an out-of-step control circuit;
  - out-of-step logic shall lock out automatic control within 90 seconds of detection; and
- al alarms and controls shall be integrated into SCADA.

3.4.4 Landsborough P210

Landsborough P210 is a pole mounted regulator and connected in open delta. Existing CL6 control schemes control each regulator separately.

This regulator scheme shall have a third phase installed and be reconfigured as a closed delta system.

The controls shall be updated to a CL7 control unit such that:

- all units regulate and tap together in a master follower style scheme;
  - for ground mount option, a three phase CL7 module shall be employed;
  - for "adjacent pole option", single phase CL7 running communicating over fibre optic can be used;
- each tank tap position is monitored and fed back into an out-of-step control circuit;
  - out-of-step logic shall lock out automatic control within 90 seconds of detection; and
- all alarms and controls shall be integrated into SCADA.

3.5 Admittance balancing

The ground fault neutraliser uses a tuned inductance (Petersen Coil / Arc Suppression Coil) matched to the capacitance of the distribution system. The 3 phase 22kV distribution system ex MRO zone substation contains approximately 942km of overhead conductor length (excluding SWER). Of this 942km, 458km (45 per cent) is single phase. Whilst planning philosophies have always attempted to balance the single phase system, inevitably this is difficult to achieve. In order to balance the capacitance of the three phase system such that the ASC can be correctly tuned, balancing substations will be placed at nodes on the system that utilise low voltage capacitors to inject the missing capacitance onto the system.

Note: Balance does not refer to the balancing of load. System balance is required from a capacitance-to-ground perspective and affected by route length and single phase connected distribution equipment.

A reconciliation of all 22kV overhead and underground lines routes shall be conducted to assess the scope of the network balancing requirements.

The following steps shall be outworked prior to GFN installation;

1. Consolidate all "Single Phase" and "unknown" conductor into the "BR", "RW" or "WB" categories
   (i) validate "Single Phase" and "unknown" conductor where required
   (ii) spot check the validity of current phasing information
2. Consolidate all single phase transformers on the 22kV system and assign to one of the "BR", "RW" or "WB" categories
3. Ascertain the construction types for all sections
   (i) indicate whether LV subsidiary exists
4. Consolidate all "1 Phase" and "unknown phase" 22kV cable and assign phase information
5. If single phase circuits are used underground, ascertain the design principles behind the single phase underground sections
   (i) conductor type, two or three core?
   (ii) treatment of the unused core (earthed or phase bonded)—if bonded, to what phase?

The course balance shall look at sections of the system in 'switchable blocks' and for any re-phasing and finite admittance balancing opportunities in order to balance out the single phase route lengths and large single phase spurs where the capacitance is fairly easy to approximate.

A tuneable balancing approach shall then look at the system again in switchable blocks for the application of 3-phase admittance balancing substations.

The use of 3-phase admittance balancing substations will provide accurate capacitive balancing in each section. Admittance balancing substations shall be placed at the following locations to enable switching of balanced blocks of the system. These locations are listed below:

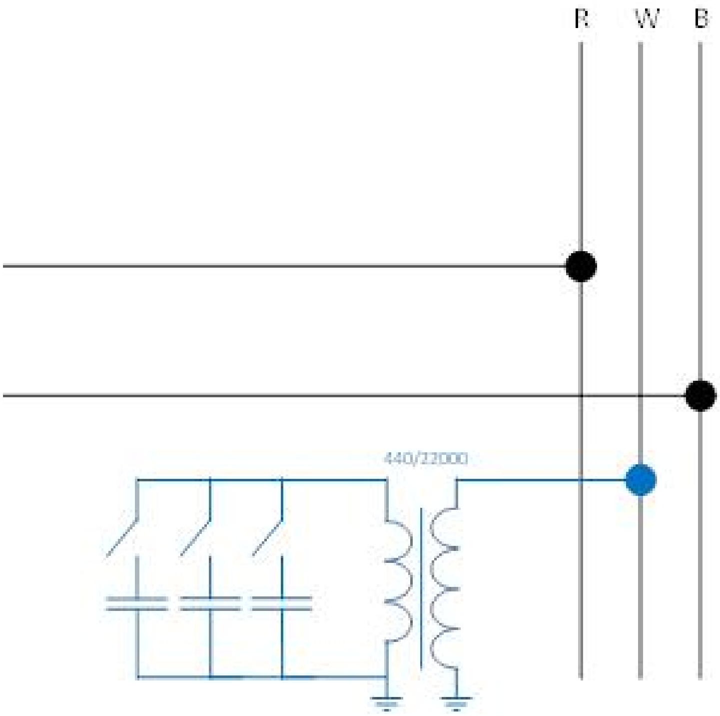
Table 4 3-phase balancing unit locations

Location (1)	Location (2)	Location (3)
MRO2 feeder exist	Tarnagulla P2 ACR	Landsborough 210
MRO4 feeder exist	Avoca P289 ACR	Cherry Tree Creek 1
MRO5 feeder exist	Avoca North P33 ACR	Moonambeel 297
MRO6 feeder exist	Switch 15339 (MRO4)MRO4 27	Moolort North 1
MRO7 feeder exist	Switch 23650 (MRO4)Park Rd 2	Eddington 1
MRO8 feeder exist	Switch 28153 (MRO6)MRO6 70	Shelbourne 45
Dunolly P251 ACR	Switch 14282 (MRO7)Carisbrook 76	Moonambeel 222
Dunolly P60 ACR	Switch 41453 (MRO5)Burns Tie 34	Tarnagulla 211
Moonambel P1 ACR	Switch 29553 (MRO8)Mt Lonarch 1	Dunolly 304
Moonambel P218 ACR	Avoca 502	Carisbrooke 90
Talbot P3	Moonambel 349	Avoca North 39

The design of these admittance compensating banks involves the use of the following:

- single phase 22kV/480V pole mount transformer:
  - one HV bushing to be solidly earthed and run at 12.7kV nominal;
  - SWER transformer considered but will not cope with the 22kV TOV requirements;
- control box consisting of:
  - appropriate MCB;
  - 415V LV capacitor cans, individually switched in series and/or parallel to achieve required capacitance; and
  - required telemetry and monitoring over 3G.

Figure 4 Admittance balancing concept



The blended approach to admittance balancing is designed to cater for the historical use of single phase spur lines, single phase cable and the variability in capacitive balancing. The number of re-phasing sites, single phase balancing units and 3 phase balancing units are also informed by experience of GSB and WND and scaled to the relative network parameter of this substation.

Table 5 Balancing requirements summary

Balancing concept	Number of sites
Re-phasing Sites	39
Single Phase Balancing Units	3
3 Phase Balancing Units	33

3.6 Automatic Circuit Reclosers (ACRs) and remotely controlled gas switches

Each RVE or VWVE ACR on the MRO network should be replaced with the current standard Schneider N27 ACR which has inbuilt voltage measurement.

Table 6 ACR replacements

Name	Operating voltage	Phase code	ACR model
Avoca P61	22kV	RWB	RVE

Each ACR or remote controlled gas switch requires a modern control box which has required programmable functions and up to date firmware. ACR and gas switch control box replacements are required (for CAPM5 or GCR300 control boxes) in order to:

- automatically detect REFCL operation and prevent incorrect operations de-energising customers;
- provide advanced fault locating algorithms capable of detecting REFCL fault confirmation tests; and
- continue to operate in the traditional manner automatically when REFCL is not in operation.

Table 7 Control box replacements

Name	Control Box model
AVOCA NORTH P33	PTCC-CAPM5
MOONAMBEL P1	PTCC-CAPM5
MOONAMBEL P218	PTCC-CAPM5
DUNOLLY P60	PTCC-CAPM5
TALBOT P3	PTCC CAPM5
AVOCA P289	PTCC CAPM5

Table 8 ACR and control box requirements summary

Units	Number of sites
ACR replacements	1
Control box replacements	6

3.7 Fuse savers

HV Fuses pose a difficulty in operating a network with a REFCL. Maintaining capacitive balance is critical in the network, and scenarios that result in 1 or 2 out of 3 fuses blowing in a 3 phase section, such as phase-phase faults can result in large capacitive imbalances. These imbalances can result in loss of REFCL sensitivity, REFCL maloperations resulting in widespread outages or REFCL backup schemes operating to remove the REFCL from service.

Fuse Savers are to be installed as a 3 phase ganged unit such that when any individual phase operates for a fault, all 3 phases open in unison de-energising a balanced section of the network regardless of the fault type.

Fuse Savers are required to operate for any fused section with a downstream network capacitive charging current of 540 mA or greater.

Table 9 Fuse saver requirements

Units	Number of sites
Fuse savers	42

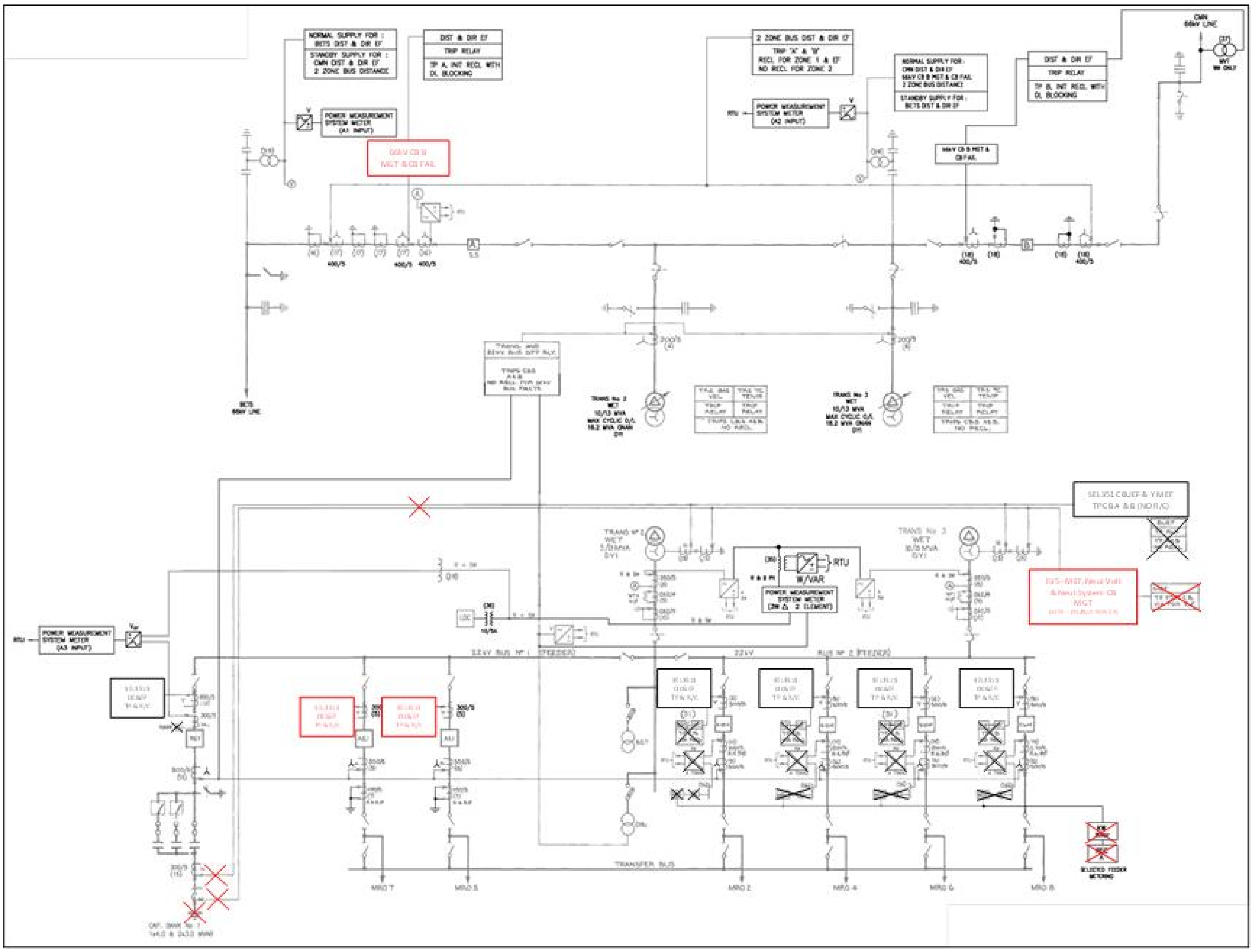
3.8 HV underground cable

Experience from REFCL testing has shown that a percentage of HV underground cable is likely to experience failure due to elevated phase to earth voltages experienced in a resonant network. An allowance for cable failure is to be made for the transition to resonant earthing.

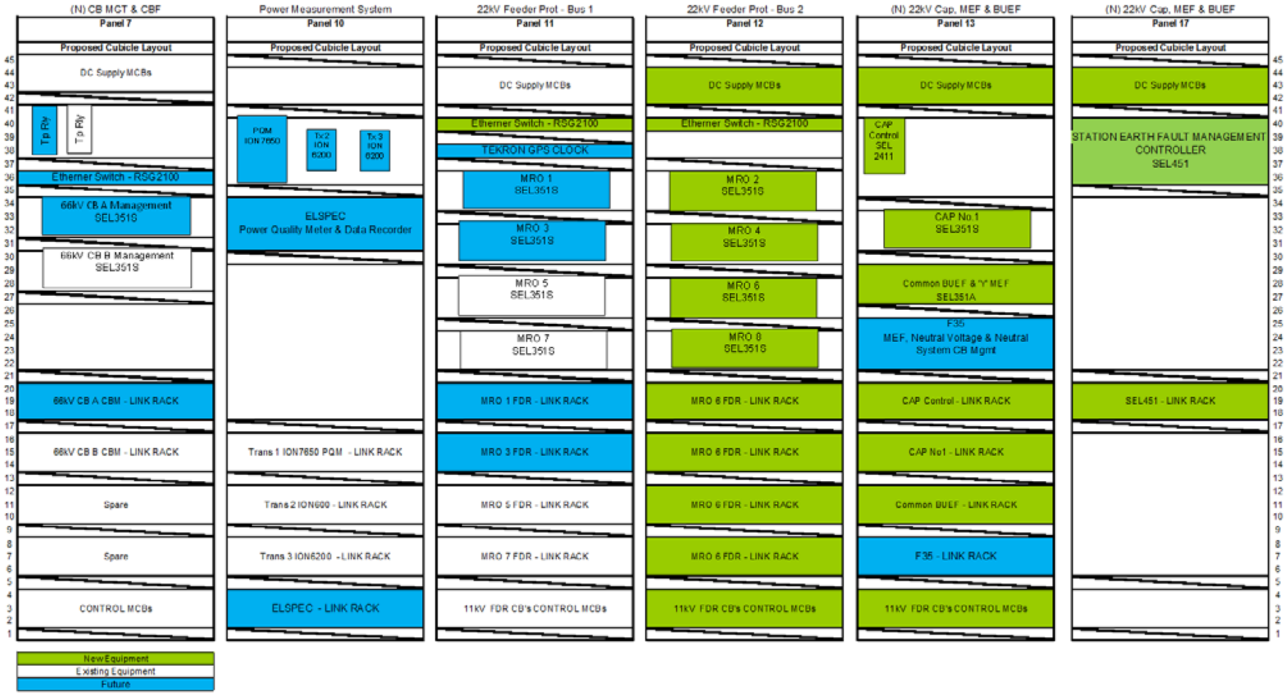
Table 10 HV underground cable requirements

Location	Length (m)
Cable failure length	163

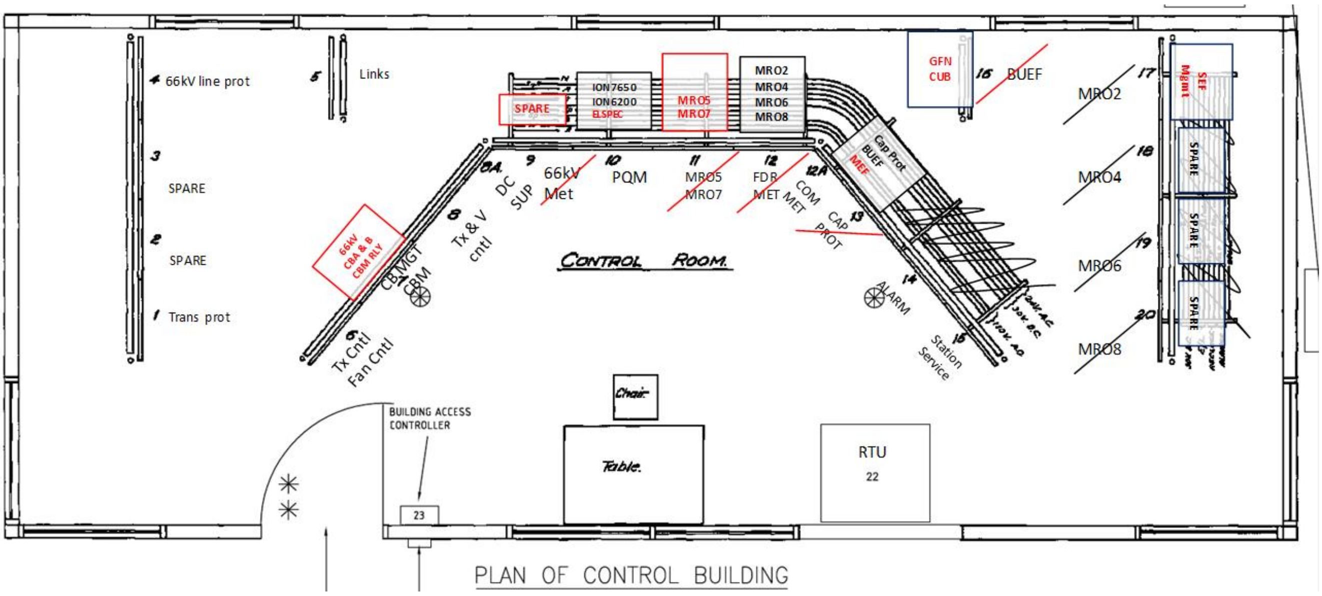
4 Appendix A: protection schematic



5 Appendix B: suggested panel layout



6 Appendix C: suggested control room layout



7 Appendix D: ethernet and sub-LAN connections