ELECTRICITY NETWORKS

Asset Strategy and Performance

Functional Scope

Functional Scope Created	**02/06/2017**	**By**	Vis Visahan		
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Project Title	Ballarat North (**BAN**) REFCL Installation				
Network No. and F/C					
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Project Engineer					
System Planning Engineer	Vis Visahan				
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Plant and Stations Engineer					
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Version	Date	Changes	Responsible Officer
1.0	02/06/2017	Original	V.Visahan
1.1	26/06/2017	Added Protection and Control Requirements	L Jayasuriya
1.2	27/07/2017	Reviewed balancing unit and auto-changeover requirements.	V.Hadya
1.3	06/02/2018	Reviewed capacitor bank works	D. Jutrisa
1.4	15/02/2018	Reviewed capacitor bank VAR control	L Jayasuriya

1 Project overview

This project scope covers the migration of the Ballarat North zone substation (**BAN**) 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;
- 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
- 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
  - 750 volts within 500 milliseconds
  - 250 volts within 2 seconds
- during diagnostic tests for high impedance faults, to limit:
  - fault current to 0.5 amps or less
  - 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
- 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 Ballarat North zone substation

Ballarat North 66/22 kV zone substation is a switched station consisting of three 20/40 MVA transformers and 3 capacitor banks of 2 x 3Mvar, 2 x 3MVar and 1 x 3MVar. It is located adjacent to the old Ballarat 'B' power station building on the edge of the Ballarat Powercor depot and office site. The zone substation was formerly the switchyard of the power station which was initially established in the 1940's and now supplies twelve distribution feeders (22kV) which supply the Ballarat CBD and an area from Clunes to Daylesford in the north and north east.

Table 1 BAN: existing characteristics (zone substation)

Zone substation	Volume
Feeders	12
Zone substation transformers	3
22kV buses	3
Capacitor banks	3
Station service transformers	2
22kV circuit breakers (switching configuration)	17 (Fully Switched)

Table 2 BAN: existing characteristics (network)

Network	Volume
Total route length (km)	1420
Underground cable length (km)	74
Overhead line length (km)	1346
Underground network (%)	5.21%
Overhead single phase	629
Estimated network capacitance (A)	292
Distribution transformers	3964
HV regulator sites	20

Network	Volume
Fuses	3648
ACRs	24
Surge arrestor sites	2,183
HV customers	9

2 ZSS requirements

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

- establish ASC bunds for three (3) REFCLs
- installation of three (3) Swedish Neutral GFN Arc Suppression Coils
- modification of the 66/22kV transformer earthing arrangement:
  - installation of Transformer Neutral Isolators and Direct Earth Switches
  - installation of 19kV surge diverters on transformer neutrals
  - installation of Neutral Bus Systems
    - bus CB's
    - NER terminations
    - ASC Terminations
    - neutral VT Installation
- upgrade station service supply to two (2) new 750kVA kiosk transformers with changeover board
- upgrade of the station service supply cabling and installation of new AC distribution board
  - install current limiting fuses on AC distribution boards
- installation of one (1) new 22kV VT and replace the existing two (2) 22kV VTs
- replace ALL substation surge arrestors with new 22kV continuous voltage units for resonant network compatibility and 10hr 24kV TOV capability
- modification of existing Capacitor Bank
  - split No.2 Capacitor bank across the No.1 and No.3 buses (2 x 3MVar).
  - remove HV earth from star point
  - install new No.2 Capacitor Bank (1 x 3MVar)
  - install new CB Management relays on all 3 capacitor banks incorporating overcurrent & earth fault functions
- install & Commission three (3) GFN control and three (3) RCC inverter cubicles
- install two (2) new Elspec Power Quality Meter
- install two (2) new ION7350 Power Quality meters
- install one (1) new ION7400 Power Quality meter
- extend station yard and earth grid as required to accommodate ASC
- install weather station
- install GE F35 MEF and Neutral Bus Management relay:
  - Master Earth Fault relay for direct earth in service applications
  - Neutral Voltage Supervision
  - Neutral Bus CB Management
  - GFN Earth Fault Management

- install three (3) SEL-451 Station Earth Fault Management relays to perform the automated control of the GFN.
- install three (3) GFN Control Units
- install two (2) ELSPEC Power Quality and Data recorders
- install one (1) ION7650 Station Power Quality Meter
- install two (2) ION7400 Power Quality meters for individual Power Quality monitoring of Bus No.2 and No.3.
- install a new SEL451 transformer controller
- upgrade feeder protection relays from the existing SR760 relays to SEL351S Feeder Management relays
- install three (3) SEL787 Transformer X Differential Protection relays.

2.1 Primary plant requirements

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

Figure 1 BAN Existing Neutral Diagram

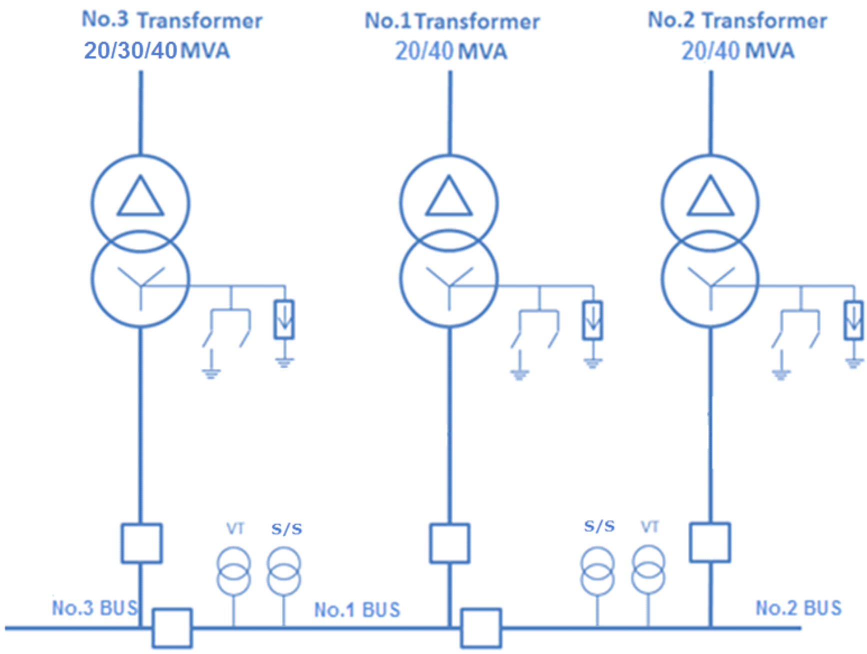
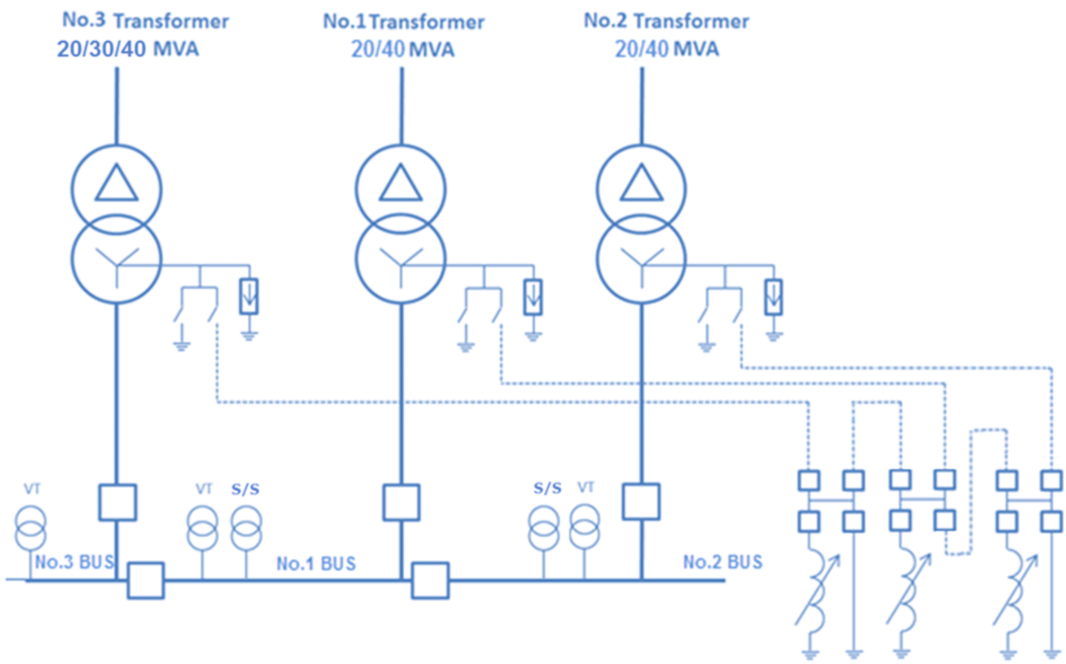


Figure 2 BAN Proposed Neutral Diagram



2.1.1 Arc suppression coil

Install 3 (3x) 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 GFN ASC shall be installed in the location of the existing capacitor bank:

- install Ground Fault Neutraliser comprising of 3x 200A ASC and residual current compensation modules 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
- install cable connections to and from the Neutral System.

2.1.2 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 phases 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
- install station class 19kV surge arresters across the transformer neutrals.

2.1.3 Zone substation capacitor bank

The existing No.2 22kV Capacitor Bank is connected in grounded star. The Capacitor Bank requires modification works to take it from a grounded star connection to an ungrounded star with an insulation rating of not less than 13kV. In addition to this, neutral balance CTs require replacement to ensure that current balance protection can be installed.

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 voltage protection (surge diverters) as per WND REFCL project
- remove the Cap Bank Neutral CTs.

The existing Capacitor Bank is to be split across Bus No.1 and No.3 (2 x 3MVAr for each bank) and a new 1 x 3MVAr to be installed onto Bus No.2 (refer to section "22kV Works" for more information).

2.1.4 Neutral system arrangement

A new kiosk type ground mounted Neutral Bus system shall be installed for each transformer neutral connection. The neutral bus system allows for integration of the ASC, a potential NER with bypass or direct earth onto the transformer neutral. In the case of BAN, connecting the bus systems in series allows for common and split 22kV bus operation.

Neutral Bus system shall be installed in the location east of the existing No.2 Capacitor Bank (to make provision for future cap bank(s)).

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

- solid grounding
- ASC in service (NER CB open) on a split bus (Bus Tie Open)
- install 3 x Neutral Bus Modules – alongside the Arc Suppression Coils.

Neutral Bus

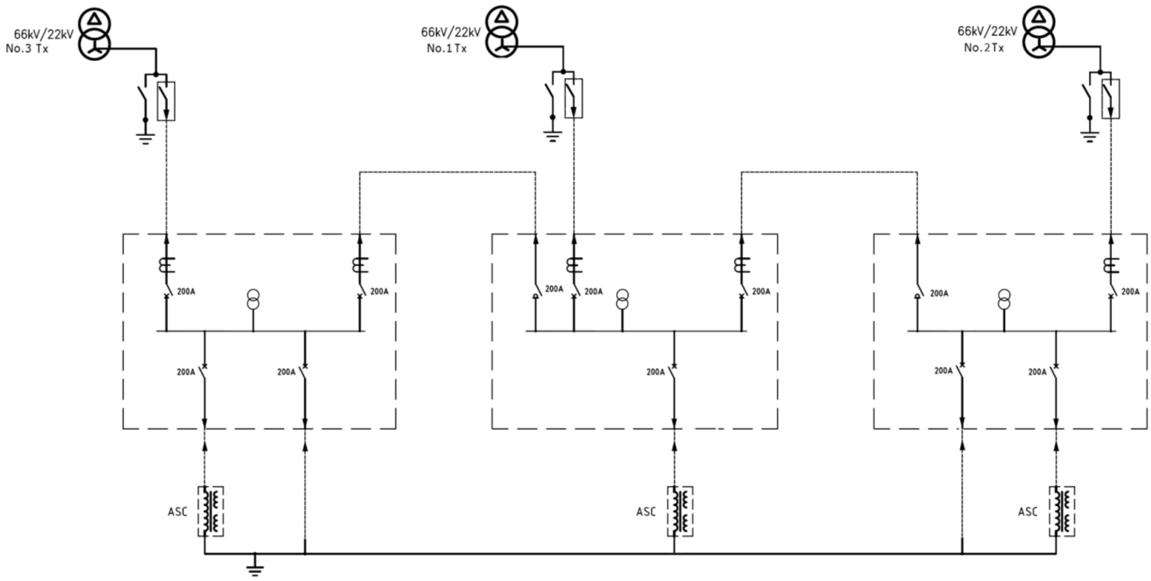
The connection to the Neutral Bus module shall be via elbow connections. Four (4) elbows are required per module for;

- transformer neutral connection
- ASC connection
- NER Connection
- bus tie Connection

Neutral Voltage Transformer

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

Figure 3 Proposed BAN neutral system single line diagram



2.1.5 Transformer earthing

The three 66/22kV, 20/40 MVA transformers in service at BAN are delta/star connected with the neutral of the star windings directly earthed.

The neutral earthing arrangement shall be modified to incorporate the new earthing arrangement with connection to the ASCs. The transformer neutral shall have a new HV insulated single phase cable installed underground from the new Neutral Bus isolator (enclosed in a lockable cage) through to HV elbow connections on the Neutral Bus modules.

External earth receptacles are required if any air cable boxes are used.

2.1.6 Neutral surge diverter

As the 22kV network is now operating as a resonant circuit, neutral surge diverters are to be installed to protect the ASC, transformer neutrals and 22kV network from overvoltages.

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.

2.1.7 22kV bus arrangement

GFN sensitivity

The BAN 22kV network consists of an estimated 1,346km of overhead line and 74km of underground cable. This leads to a network charging current of approximately 292 amps. To meet the sensitivity requirements of the GFN, it is recommended that the network be limited to 108 amps. This is a result of a sensitivity analysis surrounding a number of unknown parameters in the BAN network. In order to achieve this, the 22kV network must be rearranged, to cater for the ability to 'split' the buses.

The following requirements are necessary to split the BAN 22kV buses:

- the existing 22kV bus tie Circuit Breakers between each of the 3 22kV buses to physically split the 22kV buses and provide CT measurements for bus protection zones required for the GFN fault detection schemes in a split bus arrangement
- the existing 22kV Transformer Circuit Breakers are required in order to complete the transformer and bus protection zones
- 3 x 22kV VT's are required for transformer parallel control and GFN operation with the buses split
- 2 x Station Service Transformers are required to ensure that the GFN Inverter is available following any single fault. To prevent de-sensitising the bus protection scheme, these station service transformers shall be connected beyond circuit breakers where possible or contain 22kV CTs to remove contribution from bus protection schemes. In cases where the station service transformer is connected to the bus, it is to be protected by HV fuses.

22kV works

In order to arrange the substation in such a way that when the 22kV bus is split, the capacitive charging current is balanced across the 3 REFCLs, the following works are required.

<u>22 kV feeder rearrangement</u>

To balance the charging current among the 3 split buses the following feeders need to be rearranged at the feeder exit:

- BAN001 with BAN011
- BAN007 with BAN013

<u>Transfers from adjacent ZSS 22kV feeder(s) with non-REFCL network</u>

To identify where surge arrestors need to be replaced and how much of the network needs to be surveyed to hardened and balanced the network so that non-REFCL network can be transferred onto a REFCL network.

The following switching zone which is the transfers to non-REFCL subs that need to be considered

- BMH3 → BAN11
  - CLOSE SW30925
  - OPEN SW44642

<u>GFN Inverter Room</u>

- Install two (2) GFN Inverter Huts

Station Service and Capacitor Banks

- Separate the existing 1 x 6 + 2 x 3MVAr Capacitor Bank on Bus No.2 into two separate enclosures across Bus No.1 and Bus No.3.
  - install 22kV Capacitor Bank Circuit Breakers on Bus No.1 and No.3. The Capacitor Bank on Bus No.1 is to have a 2 x 3MVAr Capacitor Bank and the capacitor bank on Bus No.3 a 2 x 3MVAr Capacitor Bank
  - install new step switches to facilitate switching of each step individually
  - reuse 2 x 3MVAr of the existing bank for Bus No.1 and install a new 2 x 3MVAr Capacitor Bank on Bus No.3
  - the new Capacitor Bank is to be an ungrounded star with an insulation rating of not less than 13kV at the neutral point. Refer to Figure 4 below ABB Abbacus Capacitor Bank at CDN.
- The existing Bus No.2 22kV Capacitor Bank is connected in grounded star.
  - the Capacitor Bank also requires modification works to take it from a grounded star connection to an ungrounded star with an insulation rating of not less than 13kV.
  - neutral balance CTs require replacement to ensure that current balance protection could be installed. Refer Technical Standards for specification.
- Install a new 1 x 3 MVAr Capacitor Bank on Bus No.2, with a provision to expand to a 2 x 3MVAr Capacitor Bank in the future.
  - the Capacitor Bank is to be an ungrounded star with an insulation rating of not less than 13kV at the neutral point. Refer to Figure 5 below ABB Abbacus Capacitor Bank at CDN.
- replace the existing 100kVA 22kV No.1 Station Service Kiosk Transformer with new 750kVA 22kV Station Service Kiosk Transformer
  - station Service Kiosk to include 22kV CTs to allow for removal from 22kV bus protection zones, refer Technical Standards for specification (ZD036)
  - connect to AC Changeover Board within GFN Inverter Room
- Replace the existing 100kVA 22kV No.2 Station Service Kiosk Transformer with new 750kVA 22kV Station Service Kiosk Transformer
  - station service kiosk to include 22kV CT's to allow for removal from 22kV bus protection zones, refer Technical Standards for specification (ZD036)
  - connect to AC Changeover Board within GFN Inverter Room

Figure 4 CDN ABB Abbacus Capacitor Bank

22kV Bus VT

- Install new 22kV Voltage Transformer on existing No.3 Bus extension with HV Fuses
- Replace the existing two (2) VT's
  - Construction: 5 limb, 3-phase
  - Vector Group: YNyn0yn0
  - Ratio: 22000/110/110
  - Output: 100VA per phase per secondary
  - Accuracy: Class 0.5M1P
  - Material ID (310661)

22kV Insulators

- Replace all existing under rated pin insulators with 24kV rated station post insulators.

22kV Bus Naming

Any large scale changes to the 22kV yard require that consideration is given to the naming of plant in the substation from an operational perspective. This is critical from a healthy and safety perspective as well as from an operational

Nameplates in the 22kV yard must be reviewed and any that do not conform with the new naming of primary plant must be replaced.

- Review nameplates of all 22kV Circuit Breakers, Buses, Isolators, Disconnect Switches, Earth Points and Cables.

All Primary and Secondary drawings must be reviewed and any that do not conform with the new naming of primary plant must be updated.

- Review all drawings with references to 22kV Circuit Breakers, Buses, Isolators, Disconnect Switches, Earth Points and Cables.

Particular attention shall be given to the naming of primary plant items in the operational systems to ensure that any naming changes in the field are updated in the operational software such that switching instructions are correct when printed. This requires coordination between the field works, the SCADA group and network operations.

2.1.8 22kV feeder CT's

The ability to detect 25.4 kΩ faults requires a low standing neutral voltage, and this requires a high level of accuracy in measurement to optimise network balancing. Performing diagnostic testing to confirm 25.4 kΩ faults while releasing less than 0.10 I^2T, as mandated by the Electricity Safety Act 2013, also requires very accurate current measurements.

The existing feeder CT specifications are outlined below.

Table 3 Feeder CT information

Feeder	CT Spec	Required Action
BAN001	10P100 300/5	Not suitable for sensitivity requirements, require new CT installation.
BAN002	10P100 300/5	Not suitable for sensitivity requirements, require new CT installation.
BAN003	10P100 300/5	Not suitable for sensitivity requirements, require new CT installation.

Feeder	CT Spec	Required Action
BAN004	10P100 300/5	Not suitable for sensitivity requirements, require new CT installation.
BAN005	10P100 300/5	Not suitable for sensitivity requirements, require new CT installation.
BAN006	Type 80	Not suitable for sensitivity requirements, require new CT installation.
BAN007	Type 80	Not suitable for sensitivity requirements, require new CT installation.
BAN008	Type 80	Not suitable for sensitivity requirements, require new CT installation.
BAN009	Type 80	Not suitable for sensitivity requirements, require new CT installation.
BAN011	Type 80	Not suitable for sensitivity requirements, require new CT installation.
BAN013	10P100 300/5	Not suitable for sensitivity requirements, require new CT installation.
BAN015	10P100 300/5	Not suitable for sensitivity requirements, require new CT installation.

At BAN zone substation, 12 feeder CTs need to be installed and will require associated modifications of the 22kV bus structures and civil works to facilitate their installation. An alternative option to avoid modification to bus structures was considered, this option involved complete replacement of 22kV circuit breakers and was found to be a more expensive solution.

- Review fault levels, wiring length and relay burdens and define required specification to procure PX class CTs
  - note: factory acceptance of CTs requires non-standard testing to confirm accuracy of zero sequence measurement through full range of load
- Relocation of existing bus structure to facilitate the installation of a new 22kV structure in each feeder bay that requires new CT's.
- Installation of new 22kV CT mounting structure in each feeder bay that requires new CTs
- Install CTs and modify secondary relay settings for new CT ratio's and test CT polarity.

2.1.9 Earth Grid Resistance

Experience from our REFCL trial substations and Camperdown zone substation has shown that the earth grid impedance in multiple REFCL substations negatively impacts on the ability to achieve 25.4 kΩ fault detection. In our desired range of network size (less than 108A) an earth grid impedance of 0.45 Ω will result in a neutral voltage developed in the unfaulted bus up to 1.5kV which is greater than the fault detection threshold for required capacity.

At BAN zone substation, the following works are required to reduce the earth grid impedance as low as possible.

- Site survey, earth grid and soil resistivity testing
- Detailed analysis and modelling of earth grid and soil conditions
- Design of earth grid modification works
- Additional earth stakes and earth grid installation

2.2 Civil works requirement

For neutral systems:

- Install concrete foundation pad for neutral system modules
- Install neutral cable conduit, control cable conduit and provision for solid earth grid connections
- Install neutral cable conduits from transformers to neutral system modules
- Install conduits to ASCs and solid earth grid connection
- 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
- Install bunding to EPA requirements.

For station service supplies:

- Install concrete foundation for new station service transformers
- Review station service transformer foundations and enclosure for upgrade to 750kVA. Note the existing station service is 100kVA

For new 22kV No.3 Bus VT:

- Install concrete footings for new structures
- Install control cable conduits for No.3 22kV VT
- Review concrete footings for replaced two (2) VTs

For Battery Room and Control Room:

- Wall between the battery room and control room will need to be broken down to create more space for extra cubicles in the control room.
- Refurbish the battery room to provide a suitable environment for the installation of 120V X and Y battery charger, X and Y 120V batteries, one (1) DC-DC converter cubicle and 120V and 24V isolation cubicles.

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.

2.3.1 Protection Schemes

Cubicle 1

- Note the space allocated for Cubicle No.1 has not been utilised as a permanent cubicle location due to the close proximity to the Station Service cabinet with the door open.

Cubicle 2: Station OV/UV Alarms, CB Y Trip CCT Supervision, AC Volt C/O fuses

- Remove Station OV/UV relay

Cubicle 3: Target Ann, Transformer Parallel Control, Alarm and Prot Inhibit, Gen Purpose, Fuses

- Install one (1) SEL351s No.1 Capacitor Bank Overcurrent and Earth Fault
- Install one (1) F35 Current Balance Relay and Step Switch Controls
- Install associated Test Link Racks
- Remove VRR No.1 and No.2
- Remove Transformer Parallel Control Relays
- Remove Air CB Fuses and Set Point Rack

Cubicle 4-7: Control Console

- Install labels on the mimic where controls and metering are now available via relays. These are as follows:
  - all feeders via the SEL351S CB Management relays
  - transformer No.1-3 22kV CBs via the SEL351S CB Management relays
  - 22kV BT No.1-2 and 2-3 CBs CB Management relays
  - all Transformer control and alarms that are now available via the SEL451 Transformer Parallel Control relay
  - station service indications

Cubicle 8: Target Ann, X Prot Voltage Selection, DPM Power Supply, CB Control, Indication Supervision Relays

- Remove the existing ION7650 PQM. This will now be located in Cubicle 22
- Remove the CB Control fuses will not be required for the following as it is assumed that the cables can be pulled back to the new location in cubicle 12 and 28:
  - BT 1-2 22kV CB
  - BT 2-3 22kV CB
  - Cap No.2 22kV CB
- Install one (1) DC-DC Converter
- Install one (1) Advantech TPS-1551WP Station HMI
- Install one (1) SEL3530-4 RTAC
- Install associated Test Link Racks

Cubicle 9: Target Ann, Y Prot Voltage Selection, CB Control, Ethernet supplies

- Remove CB Control fuses will not be required for all 22kV feeders as it is assumed that the cables can be pulled back to the new location in cubicle 18-20

Cubicle 11: Ethernet

- Relocate the following Ethernet equipment in Cubicle 18 to Cubicle 11:
  - RS2100 Main Ethernet Switch 01 and 02
  - 120V Supply MCBs
  - DC-DC Converters
  - 2 x FirewallS, EKI252M and CSN14

Cubicle 12: Voltage Transducers and Capacitor Bank Protection

- Remove MW/MVar Tranducers for all Feeders (this will now be via the SEL351S relays)
- Install metering requirements for the PQM and ELSPEC

Cubicle 13: High Impedance Bus Protection

- Relocate Nokia Test Equipment currently located in Cubicle 18
- Relocate Juniper Equipment currently located in Cubicle 18
- Relocate fibre terminations currently located in Cubicle 18
- Install MCBs as required

Cubicle 18: Feeder Protection Relays

- Relocate existing Ethernet equipment to Cubicle 11 (RS2100 Main switches) and Cubicle 30 (RS400 Serial Servers)
- Relocate existing Nokia Test Equipment and fibre terminations (at bottom of cubicle) to new Cubicle No.1
- Install new standard 600mm wide cubicle to replace existing Ethernet cubicle in this location
- Install four (4) new SEL-351S 22kV Feeder protection relays and associated MCBs for BAN1, BAN3, BAN5 and BAN7
- Install associated Test Link Racks

The existing SR760 relays cannot be upgraded to do IEC 61850 as required to interface with the GFN Controller. Feeder relay configuration shall 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 CTs for feeder and transformer/bus differential protection. The transformer/bus differential protection CTs shall remain undisturbed. 22kV feeder CT contributions are required by the GFN zero sequence bus admittance calculations. To facilitate the GFN connection, an extra set of neutral links will be installed on feeder link rack to permit the installation of the I_0 connection off to the GFN controller.

Cubicle 19-20: Feeder Protection Relays (2 cubicles)

- For each cubicle install:
  - one (1) new 600mm wide cubicle
  - four (4) new SEL-351S 22kV Feeder protection relays and associated MCBs
  - cubicle 19: BAN 2, 4, 6 and 8
  - cubicle 20: BAN 9,11,13,15
  - associated Test Link Racks
  - one (1) RS2100 Sublan Ethernet Switch

As noted above, the existing SR760 relays cannot be upgraded to do IEC 61850 as required to interface with the GFN Controller

Cubicle 21: 66kV CB Fail

- Remove transformer No.1 -3 22kV CB Fail relays

Cubicle 22: No.2 and No.3 Cap Bank

- Install two (2) SEL351s No.2 and 3 Capacitor Bank Overcurrent and Earth Fault

- Install two (2) F35 No.2 and 3 Capacitor Bank Current Balance Relay and Step Switch Controls
- Install one (1) SEL451 VAR Control
- Install associated Test Link Racks

The VAR controller will need to be programmed to perform VAR control when the buses are split and also when the busties are closed. This will be a new config of this relay. The relay will obtain all its quantities via 61850.

Cubicle 23: TX X DIFF and GAS and T/C Prot

- Remove existing TX No.1 -3 Group 2376 X Diff Relays
- Remove Cap No.2 SEL351A OC and EF Protection
- Remove Cap No.2 Group 2743 Neutral Balance Protection
- Install equipment MCBs as required
- Install three (3) SEL 787-3 Transformer Differential Relays for No.1-3 Transformers
- Install one (1) RS2100 SubLAN switch
- Install associated Test Link Racks

This position has been chosen as the existing wiring and CT cabling for the transformer differential protection will have already been brought to this cubicle. During construction it is envisaged that the station can be run on Transformer Y Differential protection only will the existing protection is removed and the new protection is installed,

The transformer differential protection has been replaced to allow for GOOSE tripping from the GFN controller for failure of the feeder CB.

When connecting the new Transformer X Diff relays ensure that the LV CT connections are now star connections not delta.

Cubicle 24: TX Y DIFF and 22kV Bus Reclose

- Note that as bus reclose exists at this site on the 22kV Bus, an output has been included in the SEL451 Station Earth Fault Management relay to send a hardwired block signal to the Group 2282 relays. This will be wired to the reclose inhibit input of the reclose relay.

Cubicle 25: High Impedance 22kV Bus Protection

- Remove RMS 2C137 for Master Earth Fault (this will now be via the GE F35 relay)

Cubicle 26: Bus Distance and Transformer Control

- Install equipment MCBs
- Install one (1) SEL-451 VRR and Transformer Control relay
- Install one (1) RS2100-11 Ethernet Switch
- Install associated Test Link Rack
- Install Transformer Control Fibre terminations (for 2440 relays to be mounted in the yard)

The new SEL451 configured as a VRR and Transformer Controller will be able to operate in split-bus and parallel mode based on the status of the 22kV bus-ties.

The Transformer Controller requires inputs from the following protection (via GOOSE). As such ensure that these are established prior to installation of the transformer controller:

- 3 X SEL2440 Transformer I/O Management

- No.1, 2 and 3 SEL351S Transformer 22kV CB Management relays
- No.1-2 and 2-3 SEL351S Bustie 22kV CB Management relays
- 3 X SEL451 Station Earth Fault Management relay (GFN Controller)
- 1 X F35 Neutral Bus Management relays

Cubicle 27: Transformer CB Management Relays

- Remove all feeder SR760 relays
- Remove feeder repeat relay Group 2189 rack
- Install equipment Supply MCBs
- Install three (3) new SEL-351S 22kV CB Management relays for
  - No.1 Transformer 22kV CB
  - No.2 Transformer 22kV CB
  - No.3 Transformer 22kV CB
- Install associated Test Link Racks
- Install one (1) RS2100 SUB Lan switch

Cubicle 28: Bus tie CB Management Relays

- Remove all feeder SR760 relays
- Remove feeder repeat relay Group 2189 rack
- Install equipment Supply MCBs
- Install three (3) new SEL-351S 22kV CB Management relays for
  - BT 1-2 22kV CB
  - BT 2-3 22kV CB
- Install one (1) SEL351s No.1 Capacitor Bank Overcurrent and Earth Fault
- Install one (1) F35 No.1 Capacitor Bank Current Balance Relay and Step Switch Controls
- Install associated Test Link Racks

Cubicle 29: Earth Fault Management Relays

- Remove telecom line isolation
- Remove BAN5 VF Signalling and auxiliary relays
- Remove CB Status auxiliary relays for all 22kV CBs
- Install equipment Supply MCBs
- Install one (1) GE F35 Master Earth Fault, Neutral Voltage and Neutral System Management relay
- Install one (1) GE C30 I/O Module
- Install three (3) SEL451 Station Earth Fault Management relay for GFN controls
- Install associated Test Link Racks

This site will now have a VOIP phone and as such telecom line isolation is no longer required.

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
- Provide local controls and indications
- Bus Reclose blocking

GE F35 X MEF and Neutral Bus Management relay shall provide the following functions:

- Master Earth Fault relay for direct earth in service applications
- Neutral Voltage Supervision
- Neutral CB Management

Cubicle 30: Station RTU

- Remove RS400-3, RS400-4, RS400-5 are no longer required with the replacement of the feeder protection relays
- Relocate the RS400-1 and RS400-2 ethernet switches from Cubicle 18 to this cubicle

Transformer I/O Enclosure – Transformers No.1, 2 and 3

- For each transformer install one (1) transformer enclosure as per Woodend drawing VX11/151/165/1 which contains:
  - SEL2440 I/O Interface
  - MCBs, links and terminals
  - optic fibre terminal box
  - BCD Converters

2.3.2 Ground Fault Neutraliser

Cubicle 40-42: GFN Controls (3 cubicles)

- Install in each cubicle a GFN control unit comprising:
  - GFN Master Control module
  - GFN Slave Control Module
  - Windows Based PC utilising proprietary NM Term software
  - All VT & feeder I_0 CT terminations
  - All trip link outputs
  - RCC Inverter and ASC Interface
  - Panel Meters

Powercor will request through their specification process that the control unit be constructed within a standard cubicle. The 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.

VT supplies (R,W,B & V_N) are required from each bus into the GFN controller along with Feeder, Bus Tie and Transformer neutral summation (I_N) 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
- capacitive dissymmetry

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 of the new station service transformer.

2.3.3 VT supplies

VT supplies from the three 22kV Bus VTs are required to the GFN control unit. For earth fault detection, an open delta (U_N) 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 & Control of all schemes within BAN zone substation with particular reference to earth fault schemes on the 22kV network.

- SEL-351S relays will have configuration changes to introduce:
  - 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 BAN)
- An application for backup Voltage Displacement shall be considered.
- Updated Transformer protection settings for the new X Differential protection
- 22kV Bus protection settings to be reviewed with the new larger size station transformer in service which is now in the 22kV Bus protection zone. Note that if this is the case a CT will need to be installed on the HV CB of the new Station service transformers.

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

Cubicle 12: PQM and ELSPEC

- Install two (2) PQM/Data Recorder ELSPEC G5 FDR
- Install one (1) ION7650 PQM
- Install two (2) ION7400 Bus No.2 and No.3 PQMs
- Install VT Buses to be mounted on side rails where possible
- Install associated Test Link Racks

The ELSPEC Power Quality Meter is capable of recording 16 analogue & 32 digital channels of data at a sampling rate of 1000 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.

2.3.7 Control and monitoring requirements

- Remote Control and Monitoring of new:
  - SEL-351S feeder protection relays
  - SEL-351S Cap Bank No 1-3 Protection relays
  - X MEF & neutral system CB management relay GE F35
  - GFN controllers
  - ELSPEC Power Quality recorders
  - 22kV bustie 1-2 and 2-3 and transformer No.1, 2 and 3 CB management and X CB fail relays

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 & Control.

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

Given the proximity of the devices to be connected, six (6) new RuggedCom RSG-2100 switches (location specified in the panel layout drawing attached in appendices) are adequate at BAN.

- Install Gigabit backbone connection between the six new Ethernet switches
- Install fibre Ethernet links from the Feeder Protection relays, Cap Bank protection relays, 22kV CB management relays, Station EF relay, ELSPEC PQMs, GFN DPACs, RTAC & DPAC RTU to each Ethernet switch
- Move remaining serial servers under the firewall to be connected in a loop to one of the Sub-LAN switches
- Install fibre connections from GFN Interface controller (SEL-2440)

- Ensure relay configurations modified to Port Failover configuration
- Ensure Sub-LAN switch architecture configured to support fail over scenarios

A suggested Ethernet connection diagram is included in appendices.

Engineering Access

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

Time Stamping

Install new Tekron TCG-01 GPS clock, antenna and ensure that earthing is performed carefully using the standard enclosure. This is to be used for time stamping all equipment. All NTP capable equipment shall synchronise with the BAN GPS NTP server.

All non NTP capable equipment is to be left as is.

2.3.9 415/240 AC supplies

The existing station service supply transformer is located on the 22kV service bus.

The sizing of this station service transformer is inadequate for the RCC inverters used to drive faulted phase voltage to zero via the Arc Suppression Coil.

As the size of BAN network requires a split bus arrangement and three arc suppression coils, the AC supplies must ensure capacity and reliability requirements are fulfilled.

- Install two (2) new 750 KVA kiosk type station service transformers with A/C changeover facilities
- Upgrade cables to the existing station AC board. Note that now the changeover scheme within the existing station service board will not be required and will be marker OOS.
- Configure new auto-changeover board to only restore to supply 1 for loss of supply 2, i.e. not changing over immediately after supply 1 is restored, interrupting the REFCL supply unnecessarily.
- Install AC supplies for the GFN inverter to meet its specifications.

AC Board:

- Retire old AC board
- Install a new AC changeover board that will also be used as the new AC switchboard, providing circuits for;
  - Transformer tap changers, cooling and ancillary supplies x 3
  - X & Y DC Charger supplies
  - REFCL supplies
  - New Light and Power sub-board within the control room

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 and 120V chargers, batteries and DC distribution boards are located in the battery room. Due to space constraints within the control room the scope of works includes establishing a new 120V X and Y battery system and breaking down the wall between the control room and the battery room.

This will require the following changes in the battery room:

- Relocate 120V DC battery to the store room
- Relocate 24V battery and charger to spare space in the control room
- Install new 120V X and Y batteries in a cabinet
- Install new 120V X and Y battery isolation boxes
- Install 120V X and Y Battery Chargers
- Install one (1) 120V/24V DC-DC Converter to be mounted above the 120V Y Battery Charger
- Retain 120V and 24V DC supplies board

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 and any new equipment as required.

Some of the hard wired inputs and outputs will not be removed, as these alarms and controls will be rewired to the CB management relays and be available via DNP communications, e.g. feeder alarms, Cap Bank CB alarms and controls. 66kV CB alarms, statuses and remote controls

Consultation between SCADA, Operations and Network Protection & 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 Weather Station

A weather station is to be installed in order to provide monitoring of temperature, solar radiation, wind speed and humidity in the area. This provides an indication of REFCL sensitivity as it will fluctuate as the network damping (resistive leakage to earth) will vary with weather conditions. Care is to be taken when earthing the weather station to ensure there is no risk of damage to the control room from lightning strikes.

2.3.16 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 5,470 surge diverters across the 22kV three phase and single phase system.

This covers all feeders ex BAN ZSS as well as surge arrestors beyond inter-station open points shall also be upgraded to permit transfer of loads with the GFN in service.

The replacement diverters should be of 22kV continuous rating with a 10 hour 24kV TOV rating such as the ABB POLIM D 22kV arresters.

CitiPower and Powercor previous standard surge diverters were the ABB MWK 20 and POLIM D 20 arresters.

These, and all previous types except Bowthorpe ‘Type A’ arresters 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.

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 BAN distribution network contains ten 22kV regulating systems:

Table 4 BAN regulating systems

Feeder	Name	Manufacturer	Phasing	Issue
BAN011	BALLAN P160B REG	COOPER – 3 x 300A	RWB	New control box required to tap all phases together
BAN011	BARKSTEAD P190 REG	COOPER – 3 x 200A	RWB	New control box required to tap all phases together
BAN006	CLUNES P23 REG	COOPER – 2 x 100A	RWB	3-tank closed delta regulating system required with new control box
BAN009	CRESWICK REG	WILSON	RWB	No issue
BAN008	DAYFORD P15 REG	COOPER – 3 x 300A	RWB	New control box required to tap all phases together
BAN008	DAYFORD P181 REG	COOPER – 3 x 200A	RWB	New control box required to tap all phases together
BAN008	DAYFORD P80 REG	WILSON	RWB	No issue
BAN006	LEXTON P106 REG	COOPER – 1 x 50A	BR	Single phase line with single phase regulator – this must be addressed as part of balancing works
BAN011	MILLBROOK P50 REG	Brentford Electric	RW	Single phase line with single phase regulator – this must be addressed as part of balancing works
BAN006	WAUBRA P24 REG	COOPER – 2 x 100A	RWB	3-tank closed delta regulating system required with new control box

The following regulators require modification in order to meet the requirements for installing the GFN.

3.4.1 BALLAN P160B REG

Ballan P160B regulator has 3 single phase regulators. They will need to tap in step with each other, which will require a new CL7 control box as a minimum. If it is not possible for this to be fitted, a new 3 phase regulator may be required.

3.4.2 BARKSTEAD P190 REG

Barkstead P190 regulator has 3 single phase regulators. They will need to tap in step with each other, which will require a new CL7 control box as a minimum. If it is not possible for this to be fitted, a new 3 phase regulator may be required.

3.4.3 CLUNES P23 REG

Clunes P23 regulator is an open delta connected regulator; this artificially moves the neutral point of the line beyond it. This must be either replaced with a 3-phase ground type regulator, or a third single phase regulator installed on a neighbouring pole and a control scheme installed to ensure that all 3 phases tap in unison.

3.4.4 DAYFORD P15 REG

Dayford P15 regulator has 3 single phase regulators. They will need to tap in step with each other, which will require a new CL7 control box as a minimum. If it is not possible for this to be fitted, a new 3 phase regulator may be required.

3.4.5 DAYFORD P181 REG

Dayford P181 regulator has 3 single phase regulators. They will need to tap in step with each other, which will require a new CL7 control box as a minimum. If it is not possible for this to be fitted, a new 3 phase regulator may be required.

3.4.6 WAUBRA P24 REG

Waubra P24 regulator is an open delta connected regulator; this artificially moves the neutral point of the line beyond it. This must be either replaced with a 3-phase ground type regulator, or a third single phase regulator installed on a neighbouring pole and a control scheme installed to ensure that all 3 phases tap in unison.

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 BAN zone substations contains approximately 1,346 km of overhead conductor length (excluding SWER). Of this 1,346 km, 629 km (47%) is single phase or unknown. 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 (survey) 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. 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	43
Single Phase Balancing Units	32
3 Phase Balancing Units	77

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

Each RVE or VWVE ACR on the BAN 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
DAYFORD P233 ACR	22kV	RWB	VWVE27
CRESWICK P178 ACR	22kV	RWB	VWVE27
BLOWHARD P44 ACR	22kV	RWB	VWVE27
CUST MACCAINS P5 ACR	22kV	RWB	RVE
BALLAN P256 ACR	22kV	RWB	VWVE27
CLUNES P1A ACR	22kV	RWB	VWVE27
DAYFORD P103 ACR	22kV	RWB	unknown
WAUBRA P15 ACR	22kV	RWB	VWVE27
LYONVILLE P62 ACR	22kV	RWB	VWVE27

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
- continue to operate in the traditional manner automatically when REFCL is not in operation.

Table 7 Control box replacements

Name	Control box model
DOVETON ST P1 ACR CTRL	PTCC (CAPM5)
DOVETON ST P10 ACR CTRL	PTCC (CAPM5)
LYONVILLE15B-DFD CTRL	GSC-600 (CAPM3)
CRESWICK 323 CTRL	GSC-600 (CAPM3)
DAYFORD 223 CTRL	GSC-600 (CAPM3)
DEAN P4 ACR CTRL	PTCC (CAPM5)
BARKSTEAD P139 CTRL	GSC-600 (CAPM3)
BURRAL P1 AS CTRL	GSC-600 (CAPM3)
YENDON NTH 29B CTRL	GCR-300
LYONVILLE 32 CTRL	GSC-600 (CAPM3)
BALLAN 175 CTRL	GSC-600 (CAPM3)
BALLAN 297 CTRL	GSC-600 (CAPM3)
WESTERN HWY W BREWERY TAP RD CTRL	GSC-600 (CAPM3)
MILLBROOK P1 ACR CTRL	PTCC (CAPM5)
MT EGERTON P10 ACR CTRL	PTCC (CAPM5)
YENDON NTH P1A ACR CTRL	PTCC (CAPM5)
STAWELL ST P6A ACR CTRL	PTCC (CAPM5)
DAYFORD 223 CTRL	GSC-600 (CAPM3)

Name	Control box model
Ballan Auto Sect Pole 317 CTRL	GSC-600 (CAPM3)
Barkstead Auto Sect Pole 218 CTRL	GSC-600 (CAPM3)
Daylesford Auto Sect Pole 311 CTRL	GSC-600 (CAPM3)

Table 8 ACR and control box requirements summary

Units	Number of sites
ACR replacements	9
Control box replacements	21

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.

In some locations where the network fault levels are high, Fuse Savers cannot be used as they do not have the appropriate fault breaking capacity. In these situations, an ACR is required to clear faults as a three phase device else the feeder will be tripped on days of high sensitivity.

Table 9 Fuse saver requirements

Units	Number of sites
Fuse savers	59
ACRs	4

3.8 HV underground cable

Experience from REFCL testing has shown that HV underground cable can fail due to a number of flaws. Manufacturing techniques in the past have relied on steam curing of XLPE cables which can in the presence of higher voltages, result in extensive water treeing and subsequent failure. Additionally, joints and other terminations produce higher stress and can be a point of failure. The following lengths of cable are required to be replaced.

Table 10 HV underground cable requirements

Location	Length (m)
Cable failure length	10,609

3.9 Distribution switchgear

Overhead distribution switchgear has been shown to be largely resilient to the phase to earth over-voltages experienced in a resonant network. There is no planned replacement of these assets.

Resilience testing has shown that Felten and Guilleaume ground mounted kiosk switchgear is not capable of withstanding 24.2kV phase to earth voltages. The inherent design and construction of these units preclude them from any repair works and as such must be replaced.

Table 11 Felten and Guilleaume switchgear replacements

Location	Kiosk Size (kVA)
DAVEYDUKE-WARINGA NO 2	300
DAVIES SHEPPERD	1000
FALCON HARRIER	300
GILLIES-NORMAN NO1	315
HOSPITAL-VINCENT	300
KING-HOUSTON	500
LAKE GARDENS-ST JOHNS	300
MAIR-EAST	1000
WARANGA-GOLDFIELD	315

3.10 HV customer isolation substations

The Electricity Distribution Code stipulates that at the point of connection to a customer on the 22kV network, the phase to earth voltage must be no greater than 80 per cent for up to 10 seconds.

In order to maintain compliance with the code, the installation of HV isolation substations is required.

The service provider is to ensure that the detailed design of these installations considers:

- a delta zig-zag (Dzn0) vector group transformer is required to provide the isolation
- isolation substation to be sized appropriate for the total size of the customer's load, taking into account any generation
- voltage control requirements for the customer is likely to require tap changing capability for larger customers

- station service supply via the tertiary winding to provide supply to protection, metering and control circuitry
- appropriate HV source side protection to protect for faults in the substation transformer
- appropriate HV load side protection to protect for faults between the substation and customer protective devices
- note that customer protection is in some cases not at the point of connection and there is a risk of sensitive earth faults
- bunding and other environmental considerations for substations
- undergrounding of any electrical conductor between the isolation substation and customer connection

HV customer connection sizes are set out in table 12.

Table 12 Isolation substation requirements

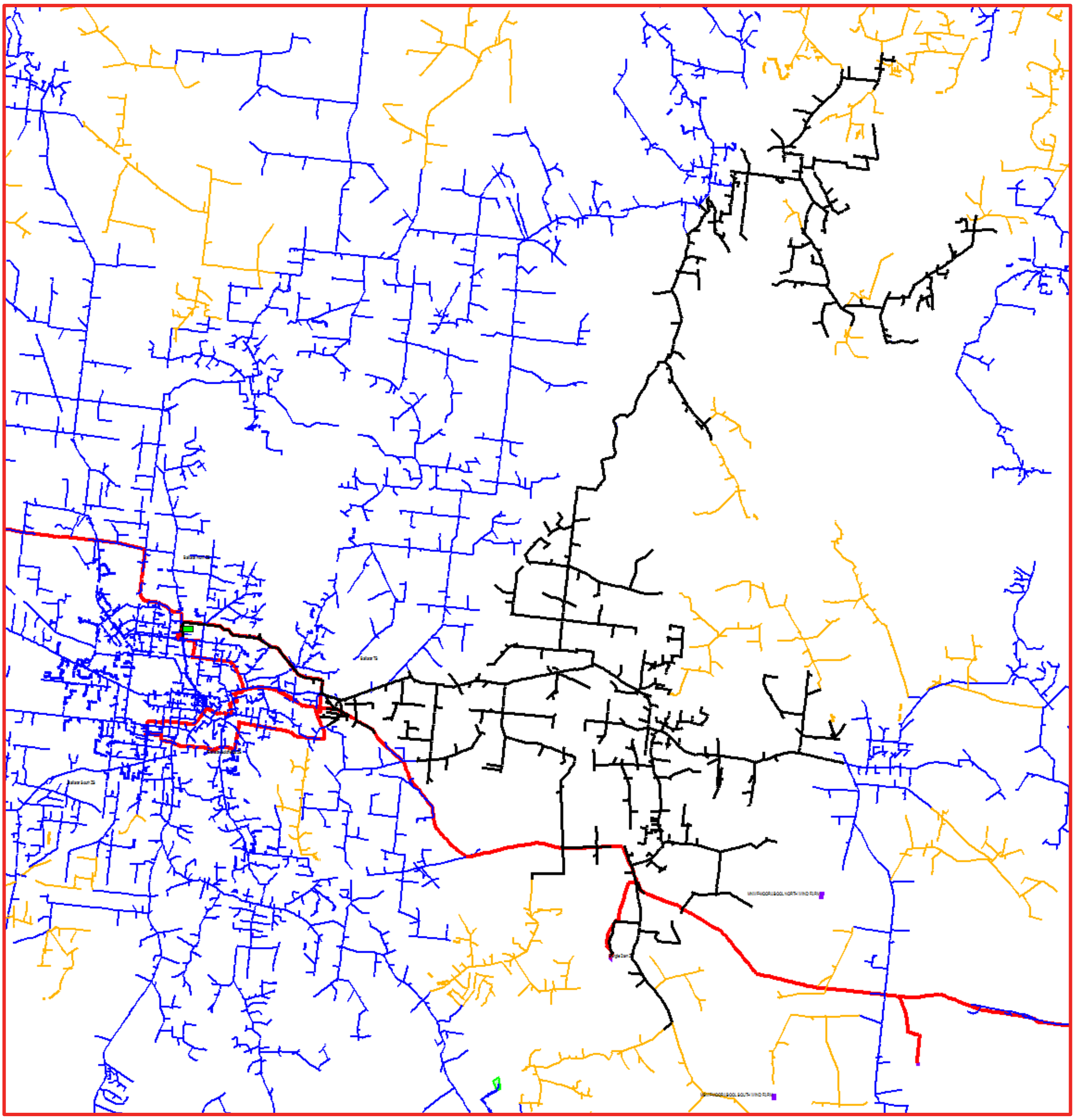
Size	Quantity
3 MVA	3
6 MVA	6

3.11 BAN011 REFCL Network Segmentation

BAN011 Feeder is a rural long feeder supplying approximately 3800 customers over a 22kV feeder coverage of 411km. The estimated charging current of this feeder is 84A. To improve REFCL performance and ability to detect high impedance faults on this feeder consistently, an isolation transformer with attached REFCL is required.

Install 1 x Isolation Transformer with REFCL protection at Barkstead P4 to segment the 22kV feeder.

Figure 5 BAN011 Feeder



3.11.1 Civil Works

- Procure easement along Spargo Creek Rd alongside Barkstead P4 and Barkstead P5
- Install 125mm HDPVC conduit from Barkstead P4 to REFCL supply transformer
- Install 125mm HDPVC conduit from supply transformer to isolation transformer
- Install 125mm HDPVC conduit from isolation transformer to Barkstead P5
- Prepare protective and system level earth grid, with earth grid impedance to be less than 0.5 Ohms
- Prepare foundations for 500kVA supply transformer
- Prepare foundations for 6 MVA Isolation Transformer
- Prepare foundations for Swedish Neutral Arc Suppression Coil
- Prepare foundations for Control Enclosure for Inverter and Control Cubicle
- Install enclosure for Inverter and Control Cubicle

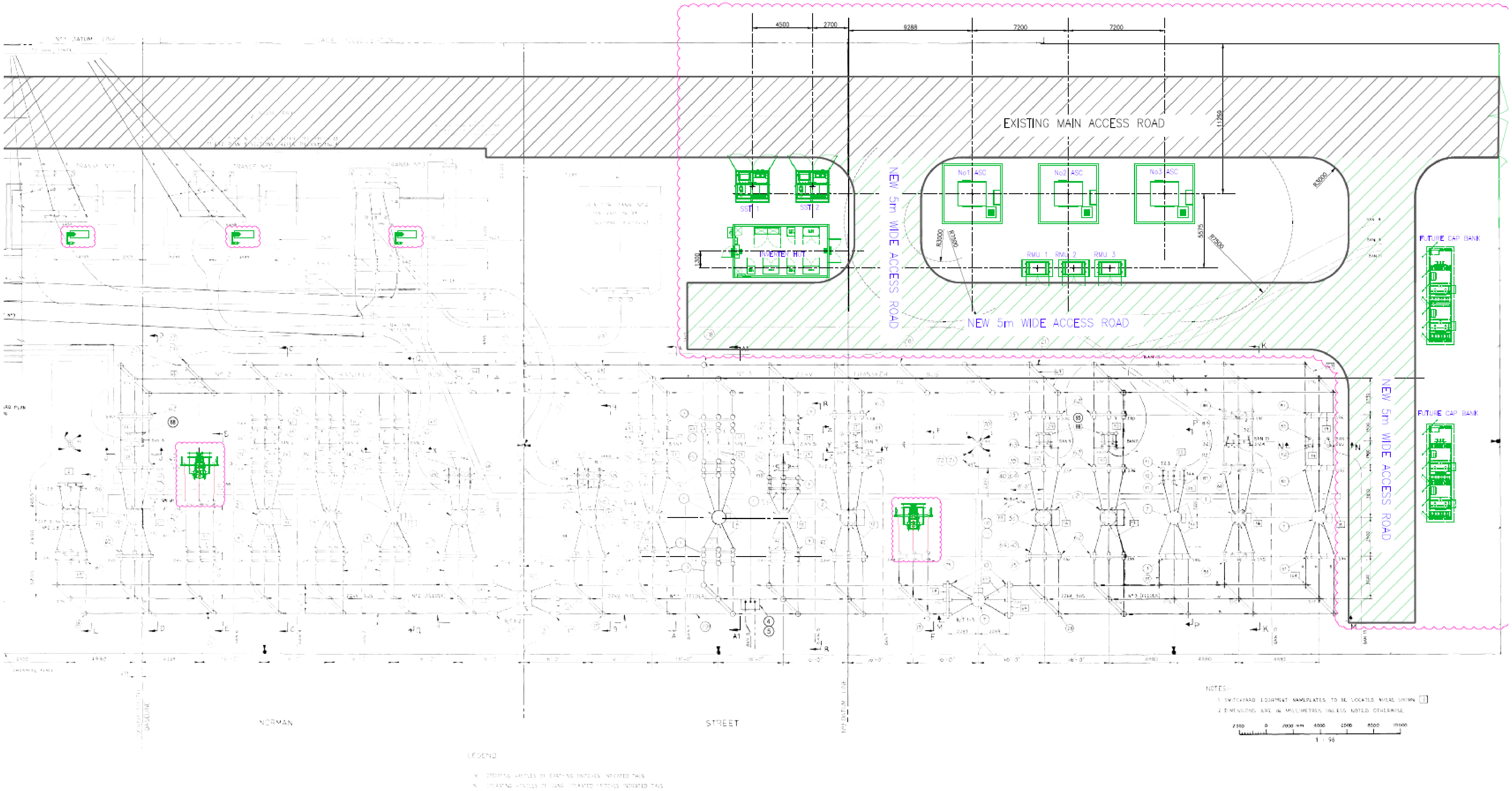
3.11.2 Primary Works

- Modify existing Barkstead P4 into a cable head structure
- Modify existing Barkstead P5 into a cable head structure
- Install 500kVA 22kV – 430V REFCL Supply Transformer
- Install 6MVA 22kV – 22kV Dz0 Isolation Transformer
  - Isolation Transformer to include OLTC, load and source side circuit breakers, protection functions and
  - install 1 x neutral bus module with connections available for:
    - transformer neutral
    - Arc Suppression Coil
    - solid ground connection
- Install Arc Suppression Coil and connect to neutral bus module and RCC inverter
- Install 22kV 185mm 3c XLPE cable from Barkstead P4 CHP to REFCL supply transformer
- Install 22kV 185mm 3c XLPE cable from REFCL supply transformer to isolation transformer
- Install 22kV 185mm 3c XLPE cable from isolation transformer to Barkstead P5 CHP

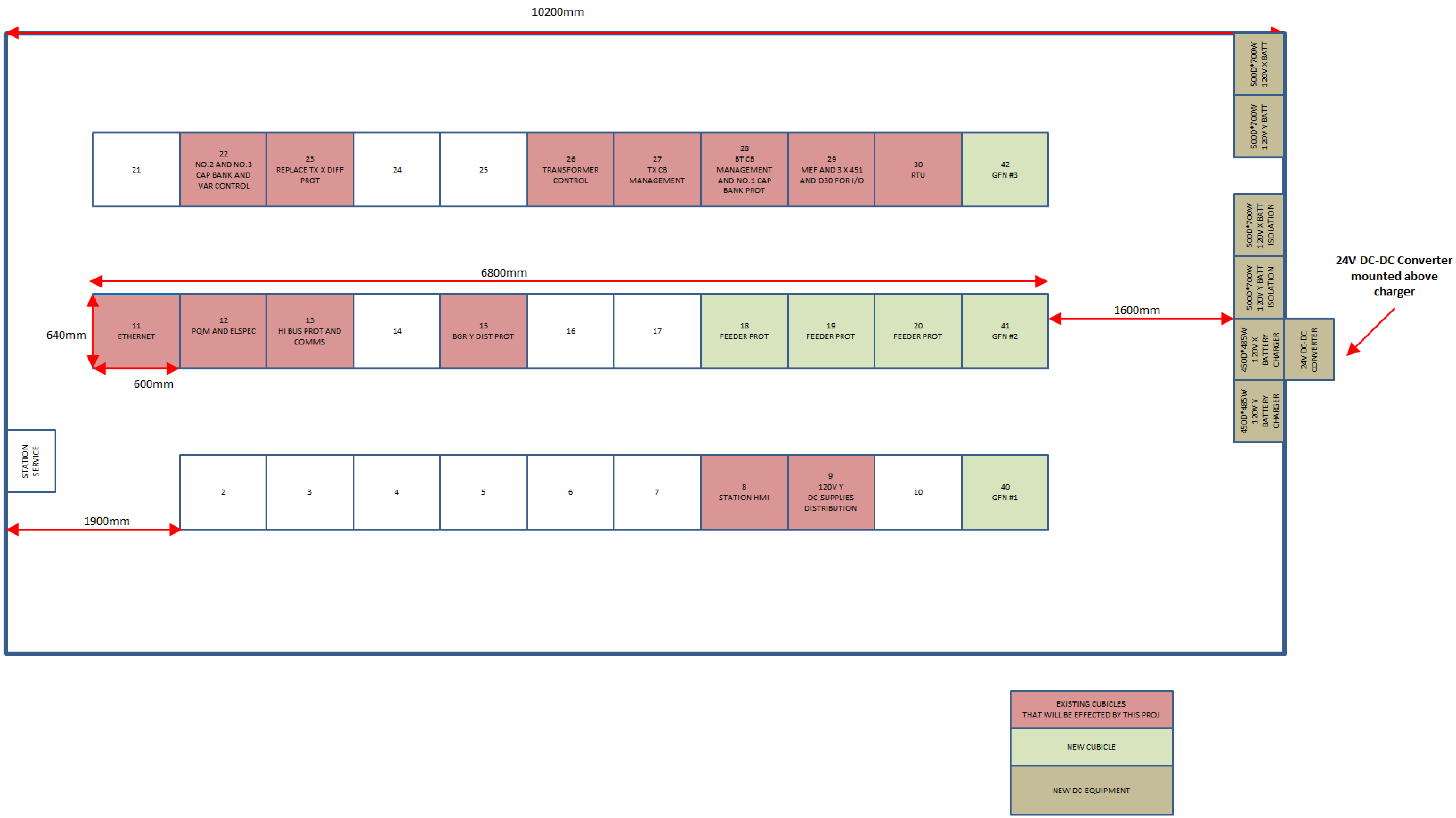
3.11.3 Secondary Works

- Install GFN Control Cubicle, RCC Inverter and Grid Balancing Cabinet within Control Enclosure
  - Fibre connection to be provided for 61850 communication to equipment within isolation transformer
- Within Isolation Transformer
  - Install 1 x SEL451 Neutral Bus Management Relay
    - Status and Controls to be wired to Neutral Bus in accordance with application guide
  - Install 1 x SEL451 Station Earth Fault Management Relay
    - All connectivity to be via IEC-61850 communication
    - Wire DC supply in accordance with application guide

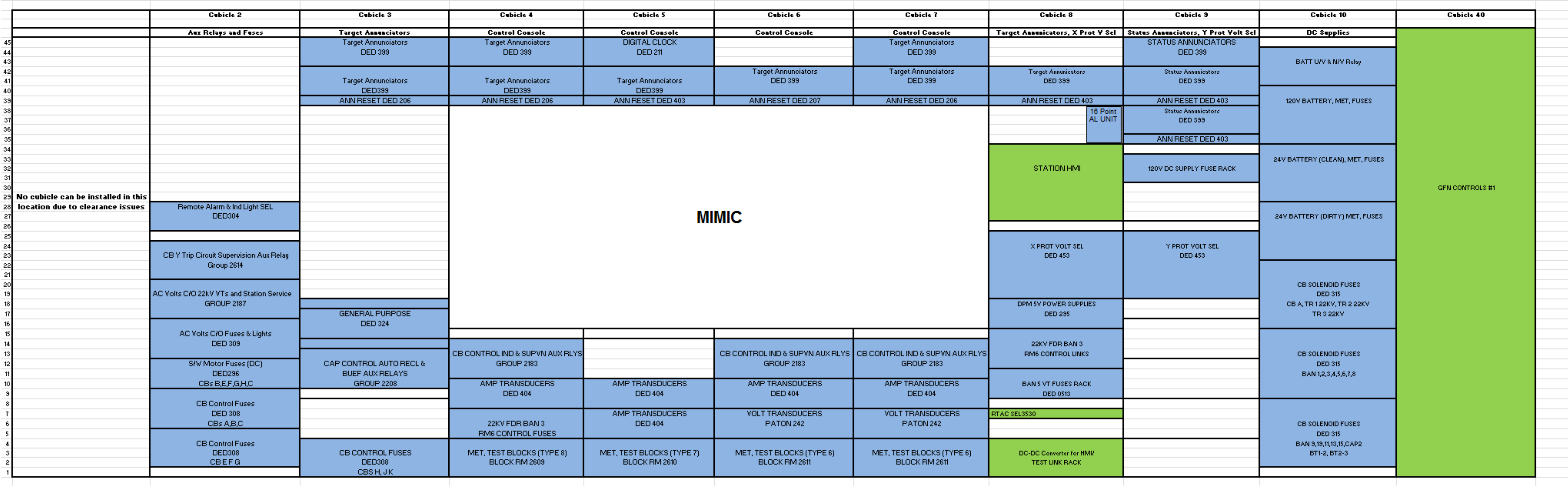
4 APPENDIX – Site General Arrangement



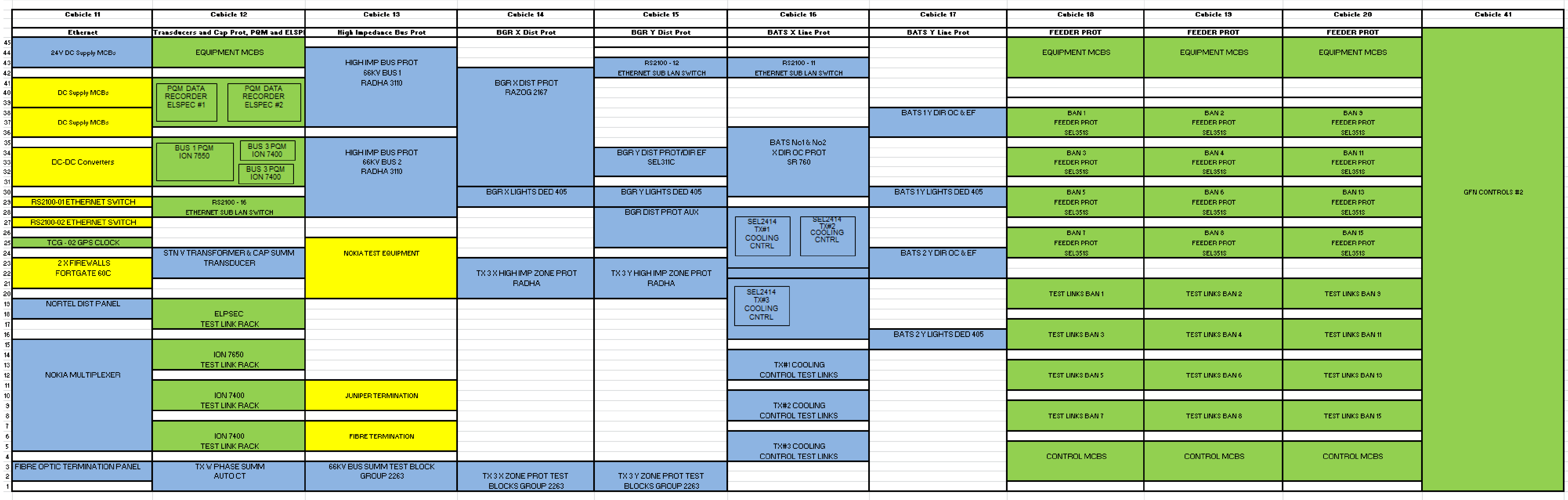
5 APPENDIX – Control Room Arrangement



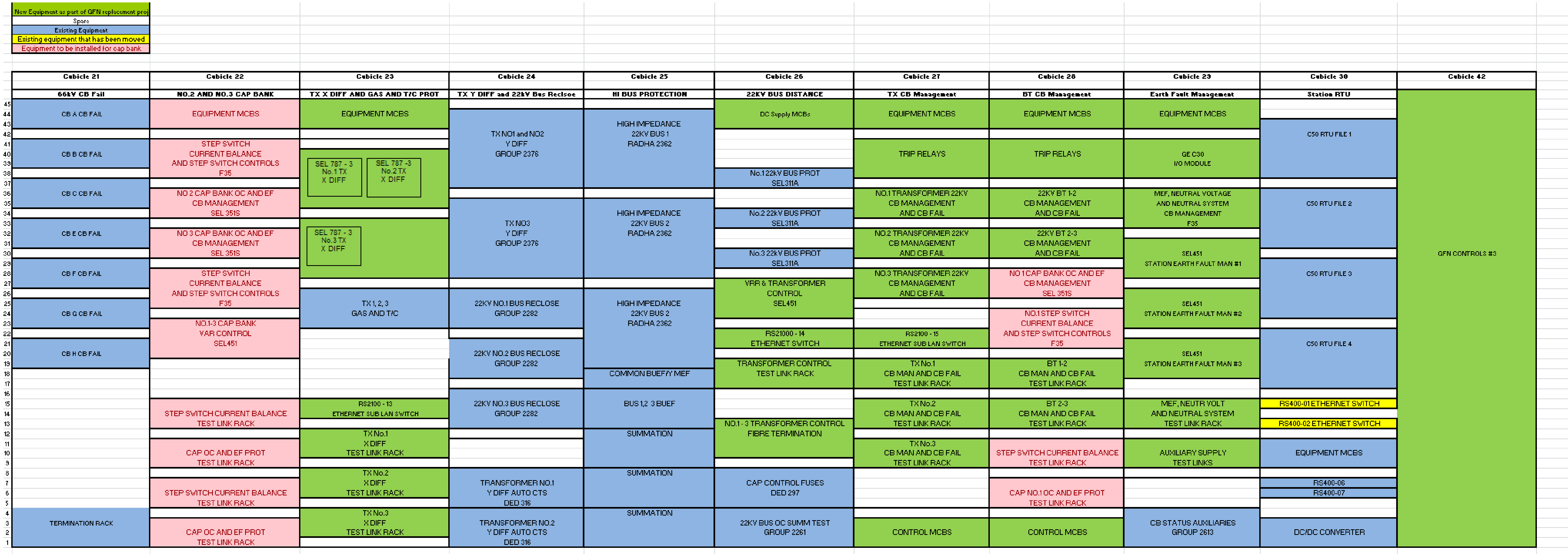
6 APPENDIX – Control Room Arrangement – Row 1



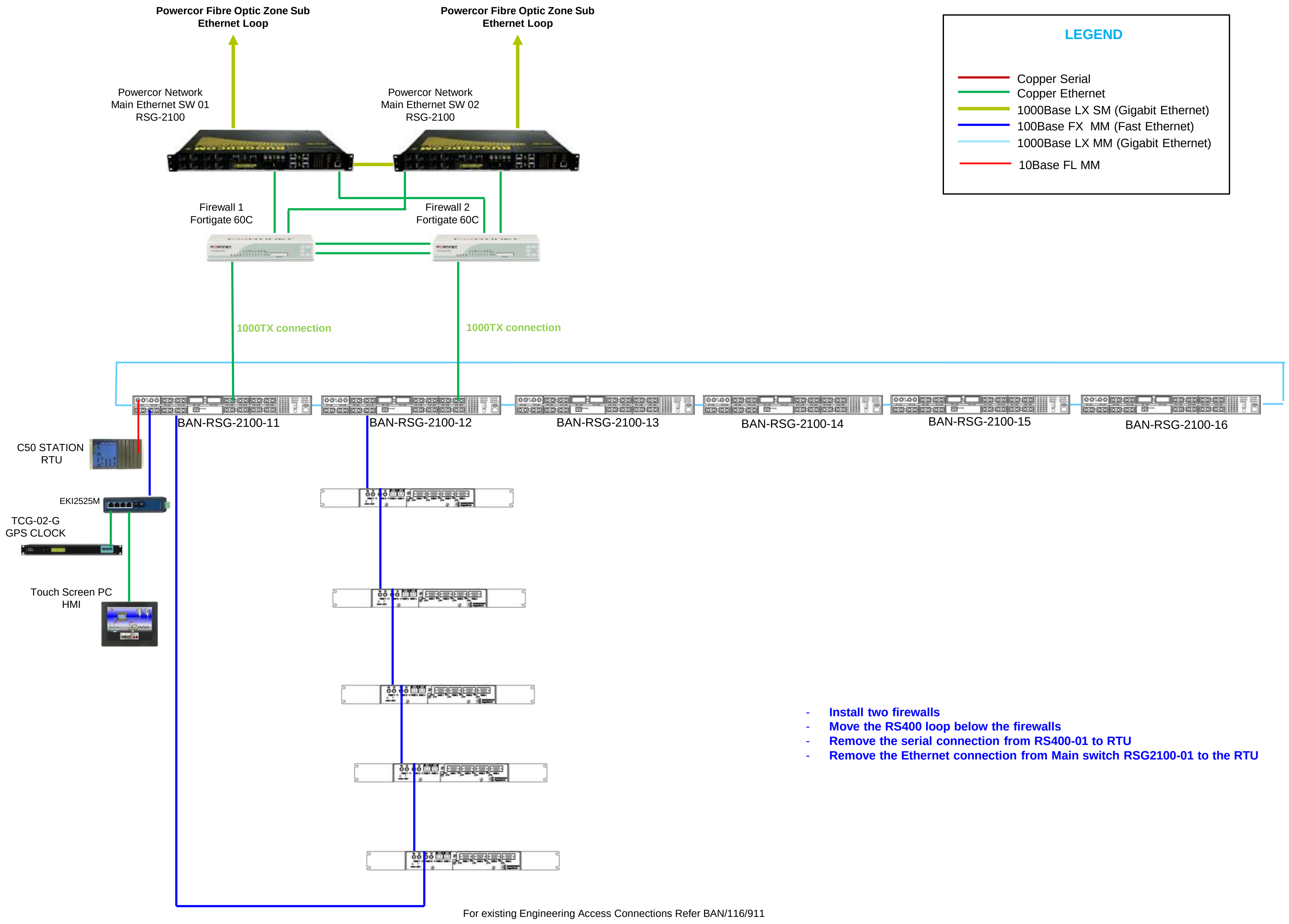
7 APPENDIX – Control Room Arrangement – Row 2



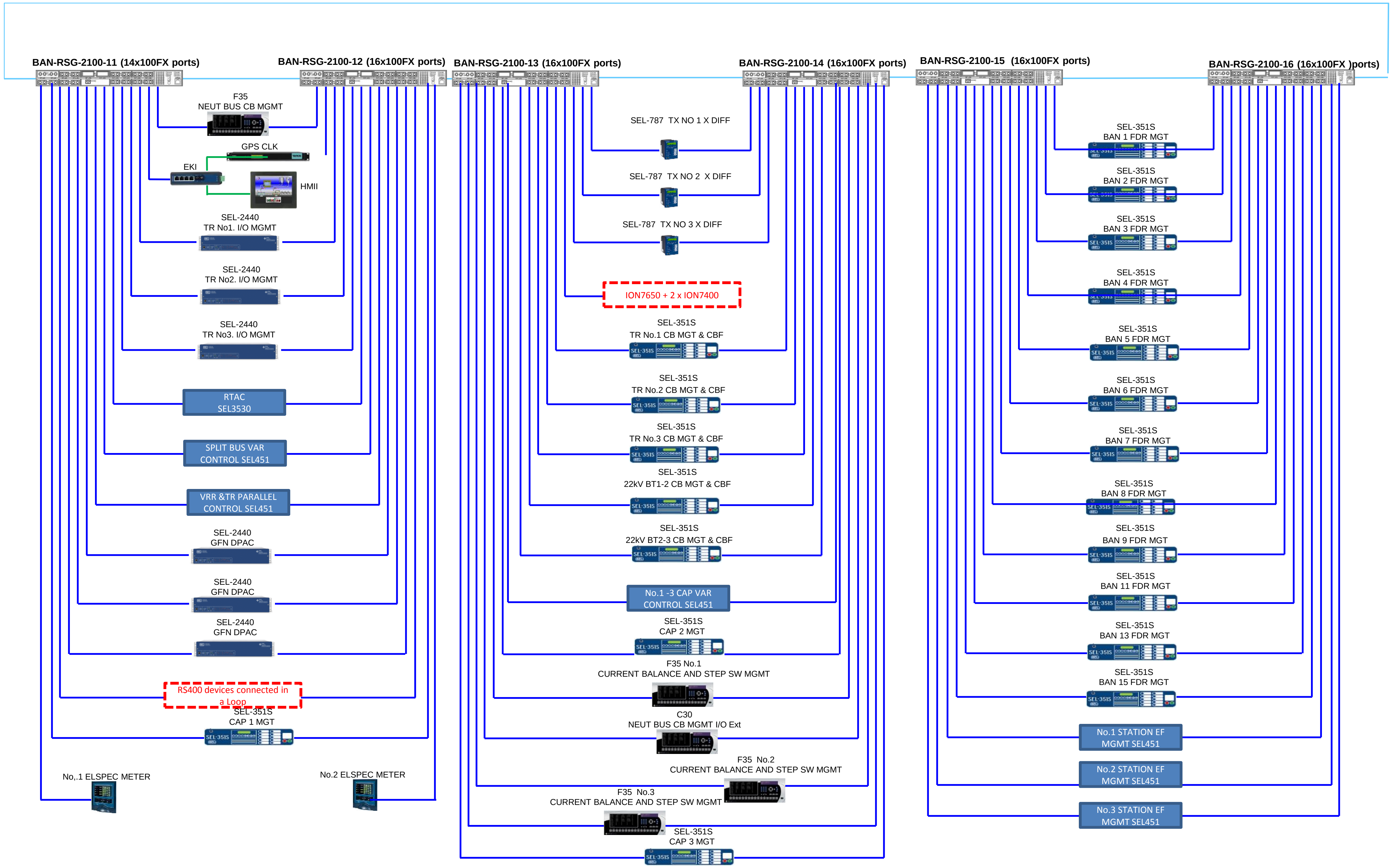
8 APPENDIX – Control Room Arrangement – Row 3



9 APPENDIX – Overall Ethernet Connections



10 APPENDIX – SUB LAN Connections



11 APPENDIX – 22kV/12.7kV Protection Schematic