Network Configuration Document – Selection for New Substations – Framework

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1. Introduction

1.1 Purpose

This framework directs the network and busbar configurations and consequent layout which are to be used for Powerlink substations. Any network and busbar configurations not provided for in this Framework will be treated as non-standard and will require recommendation from General Manager Technology and Planning, endorsement by General Manager Network Operations and approval by the Executive General Manager Delivery and Technical Solutions.

1.2 Scope

The requirements of this framework apply to all new substations and additions/reconfigurations of the network.

Busbar configurations

Where a full rebuild of an existing substation is necessary, the busbar configuration shall be in accordance with this framework. Where a partial replacement or addition is required, the existing substation busbar configuration will be assessed on a case by case basis taking present and future customer/network requirements into consideration before recommending a suitable configuration to Executive Manager Delivery and Technical Solutions.

Network configuration

Where there is a new addition or reconfiguration of the network required, the network configuration shall be in accordance with this framework.

Where replacement of the existing assets is required and it may be beneficial for the network utilisation to do so, consideration will be given to change the network configuration in accordance with this framework.

1.3 References

Document code	Document title
Electrical Safety Act	Electrical Safety Act *2002* (Qld)
Electrical Safety Regulation	Electrical Safety Regulation *2013* (Qld)
NER	National Electricity Rules
Work Health and Safety Act	Work Health and Safety Act *2011* (Qld)

1.4 Defined terms

Terms	Definition
AEMO	Australian Energy market Operator
RIT-T	Regulatory Investment Test for Transmission

1.5 Monitoring and compliance

The implementation of this framework is monitored through asset lifecycle:

1. Planning and Investment
    - Through feedback from existing customers and potential proponents.
    - Through design reviews and ensuring the appropriate busbar configuration is included in the project scope report.

- Seeking feedback from designers with regards to the level of difficulty for substation expansions or modifications and complexity of the protection systems.

2. Operation, Maintenance & Refurbishment
   - All aspects of maintainability are assessed and feedback provided to ensure that any replacement or augmentation project considers any required improvements.
   - All feedback is collected and considered when reviewing this Functional Policy to ensure identified improvements and innovative solutions are included.
3. End of Life (Dispose or Replace)
   - Prior to initiation of replacement and augmentation projects the existing network and busbar configuration is assessed taking into consideration existing and new customer requirements, stability of the network and maintainability of the equipment.
   - The busbar and network configurations are captured in multiple drawings but also in the Transmission Network Database and Energy Management System.

1.6 Risk management

In accordance with the Corporate Risk Matrix, this Framework provides an overview of the network and busbar configurations to manage safety, network operations, financial, stakeholder and legal and compliance risks associated with the electricity transmission network.

The safety and network operation risks are associated with having sufficient and adequate distances to maintain and operate electrical equipment and having sufficient redundancy to allow required maintenance outages without impacting network customers.

The financial and stakeholder risks are associated with the cost of investment, its impact on the cost of electricity, its impact on existing and new customers and Powerlink's obligations as a Network Service Provider.

Legal and compliance costs are associated with meeting all conditions of the National Electricity Rules, Transmission Authority Licence, Work Health and Safety Legislation and customer connection agreements.

Before any recommendations are made to change from this framework document, assessment is required by subject experts on network configuration (including network stability) and busbar configuration.

2. Network Configuration

2.1 Substation Layout Principles (110/132kV, 275kV, 330kV)

Below are listed standard network configurations. Application of any other network configuration will need to be assessed against a number of criteria including but not limited to:

- Customer requirements
- Impact on network stability during planned and unplanned contingencies
- Impact of outages on new and existing customers
- Complexity of protection systems
- High level investment cost
- Maintainability
- Expandability

Additionally, for connections to Powerlink's network, the following criteria must be met in the configuration of the connection:

- No credible outage on a customer's network should result in an outage of the shared network to which it is connected.
- 110kV and 132kV connections within 5km of an existing substation will typically be connected back to the nearby substation. Powerlink's experience has shown this to provide the lowest combination of cost, complexity and operability.
- 275kV and 330kV connections within 10km of existing substations will typically be connected back to the nearby substation. Powerlink's experience has shown this to provide the lowest combination of cost, complexity and operability.

Some layouts may already exist in the Powerlink network that differs from those listed in this Framework but these resulted from the network's development over time.

2.2 110 / 132kV Standard Configuration

The standard configuration used for 110kV and 132kV networks is a "U bus" or folded bus configuration. This consists of two busbars, with a bus coupler breaker, and breakers on each transformer / feeder or reactive plant element. Where two elements provide connection to the same location or function, then they should be connected to opposing bus bars.

Further information on the folded bus configuration is provided in section 3.1.2.

2.3 110 / 132kV Increased Reliability Configuration

Where a number of single or multiple connections exist, it may be preferable to utilise a disconnector selectable arrangement to increase the operational reliability of the substation. Each transformer or feeder is established utilising a disconnector to each busbar, and a bus coupler breaker is required. Reactive plant elements are able to be connected to a single bus bar.

The use of this configuration will be assessed on a case by case basis. Disconnector selectable configuration will only be considered where it is cost effective against a folded bus arrangement.

2.4 110 / 132kV Minimum Configuration

The minimum acceptable configuration for a 132kV connection is a 'tee'. A tee connection creates a three-ended feeder, increasing the complexity of protection systems and maintenance requirements. A tee connection is permissible on the 132kV network provided it can meet the following:

- The connection must be able to be readily isolated from the Powerlink network with an isolation point (including circuit breaker)
- The feeder must have duplicate high speed communications available to facilitate duplicate differential protection.
- The overall length of the entire tee connection must not exceed 30% of the overall feeder length, or 30km, whichever is the lesser.
- Where the length of the tee exceeds 300m, then the isolation point (including circuit breaker) is to be installed adjacent to the feeder.
- Where the length of the tee exceeds 30km, or where multiple transformers are installed on the tee, then it will be necessary to install circuit breakers at the remote end substation.
- Four ended (double-tee) connections will only be considered where:
    - duplicate high speed communications is available to all sites on the feeder;
    - the secondary systems can be upgraded to duplicate differential protection; and
    - the proposed configuration is accepted by the General Manager Network Operations.

Where existing network connections prevent the installation of a tee to the 132kV network, then the minimum configuration acceptable is a folded bus arrangement.

Where connection to multiple 132kV feeders is required, then the minimum configuration acceptable is a folded bus arrangement.

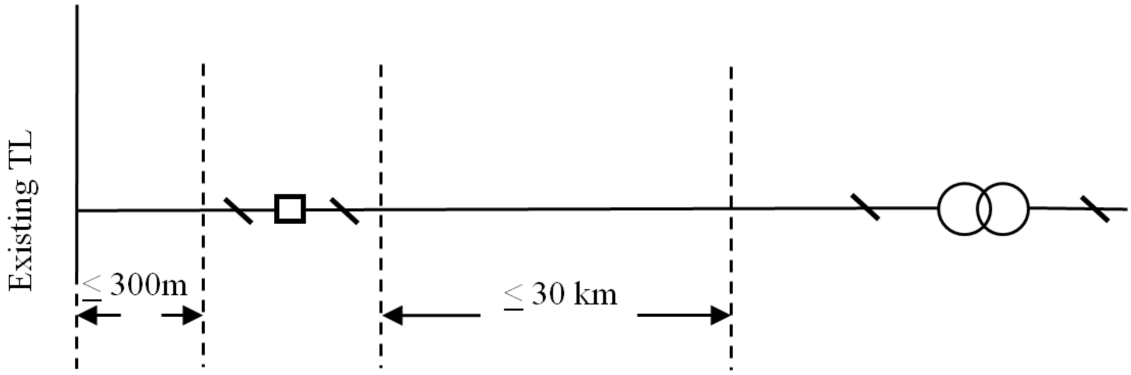

Figure 1

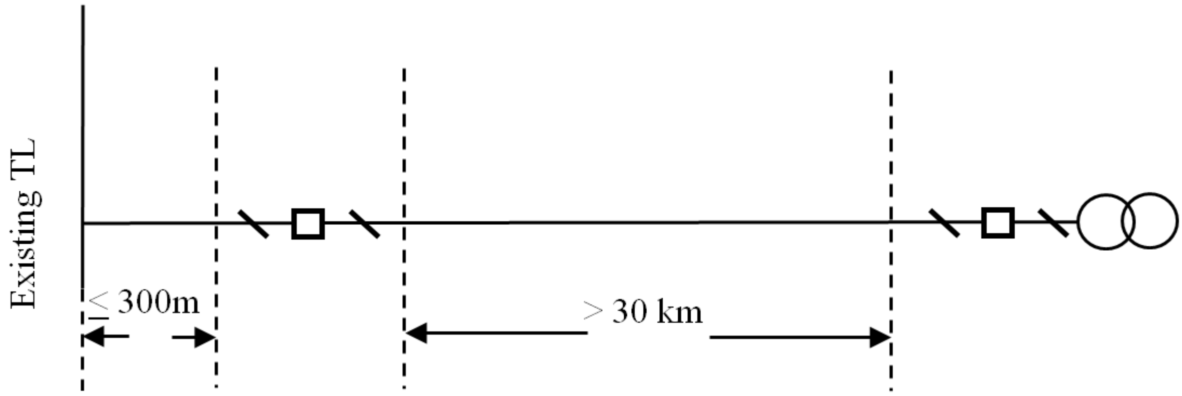

Figure 2

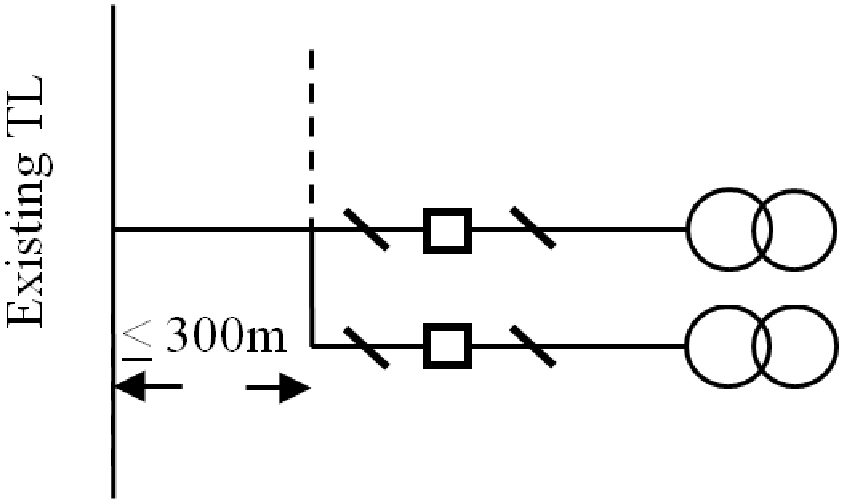

Figure 3 – Single tee connection with two transformers

2.5 275kV and 330kV Standard Configuration

The standard configuration for a 275kV or 330kV substation is a breaker and a half arrangement, comprising two busbars with 275kV diameters for connection of elements. This configuration provides high reliability, allows for maintenance outages and maximises operational flexibility.

Further information on the breaker and a half configuration is provided in section 3.1.1.

2.6 275kV and 330kV Minimum Configuration

The minimum acceptable configuration for a 275kV or 330kV connection is a ‘mesh’ arrangement, consisting of two busbars, one fully populated CB ½ diameter, and one single CB diameter. Additional connections, such as those for an additional transformer, can be in the form of extension of the partially populated diameter, or may be as single bus connections.

Connections via tees to the 275kV and 330kV network are not considered an acceptable solution.

2.6.1 Outages

Access to customer outages should be such that there is not a significant impost on the backbone shared network. That is, disconnectors should be installed to facilitate the outage without needing to take the shared network element out of service.

2.7 Connection to end-of-life assets

If a customer proposes to connect to the existing network assets which are identified to be reaching the end of their service life within the next 10 years (in the latest Asset Management Plan), then the customer will be provided with information and high level estimated costs involved with either extending asset lives (if feasible) or estimated cost of the assets replacement. In addition, an alternative connection point will be suggested for customer consideration.

Where assets have been identified as reaching their end of life within the next 10 years, Powerlink will undertake to provide information on the likely configuration and what the impact on the connection might be. Considerations include changes in fault level, thermal capacity or availability of assets. This may not be the direct asset being connected to, but where assets being removed may result in changes to the wider network impacting on the connection.

Where the expected end of service life for the asset is not identified in the 10 year Asset Management Plan, then it will be assumed that the customer will accept outages in the future to allow for life extension or asset replacement.

Additionally, Powerlink is required to undertake analysis and consultation (in the form of a RIT-T) where changes in the network result in significant impacts to any market participant.

2.8 Connection of Hub Substation

Where multiple parties are connecting in close proximity, Powerlink may consider the connection of multiple parties to a single substation to minimise connection costs and potential impact on the other parts of the network.

3. Bus Bar Layout

The following busbar configurations and consequent layouts will be used for Powerlink substations. Due to inherent differences in reliability and availability between air insulated substation (AIS) equipment and gas insulated substation (GIS) equipment, it is appropriate that busbar layouts for each equipment type be considered separately. In addition the positioning of gas barriers in GIS equipment is defined to the extent of minimising affected plant during isolation and repair.

3.1 Air Insulated Substations

3.1.1 High Reliability Configuration

AIS substations required to supply loads which call for high reliability and availability shall be laid out in a “breaker and a half” configuration (see Figures 4 and 5). Substations serving major customers and/or an integral part of the transmission network are examples that may require this busbar configuration. Whilst this arrangement allows flexibility for operations and maintenance it is also the higher cost option due to the number of primary plant items.

This category includes main grid substations 275kV and above. Generally 110kV or 132kV substations would not fit this category though possible exceptions are the replacement of legacy substations at power stations or specific customer loads that require high-reliability (generally by negotiation with the customer).

The relative positioning of feeder and transformer bays within the substation is determined on a case by case basis for each site. However consideration needs to be given to the criticality of through-flow versus load when positioning bays within diameters and on busbars. Similarly, potential maximum busbar currents should be considered when positioning loads and sources.

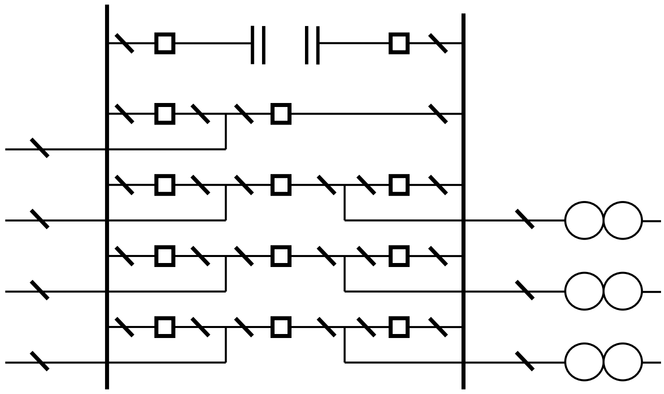

Figure 4: Typical Breaker and a Half Configuration (through-flow interconnection not critical)

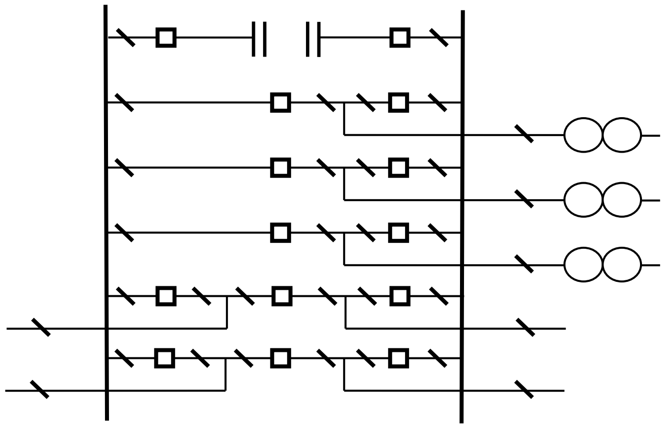

Figure 5: Typical Breaker and a Half Configuration (through-flow interconnection critical)

Minimum Configuration

Where breaker and a half substations are to be developed in stages or the ultimate size is small, there is a minimum build configuration to ensure adequate reliability and availability. This may vary depending on the function of the substation and its connections. Examples of minimum breaker and a half substation configuration are provided in figures 6, 7, 8 & 9.

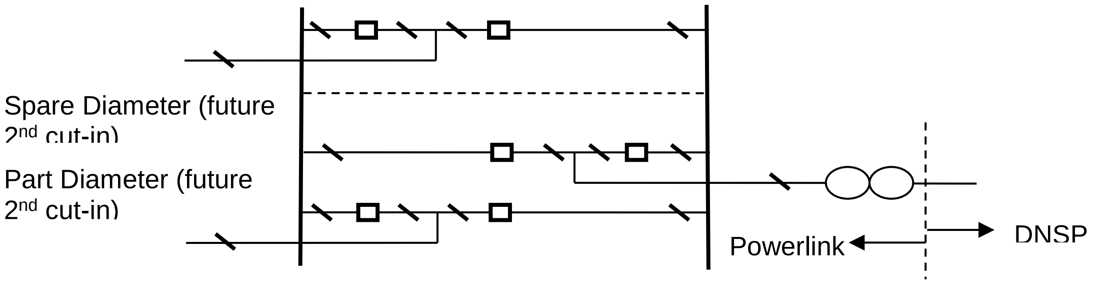

Figure 6: Breaker and a Half Layout (through-flow interconnection not critical)

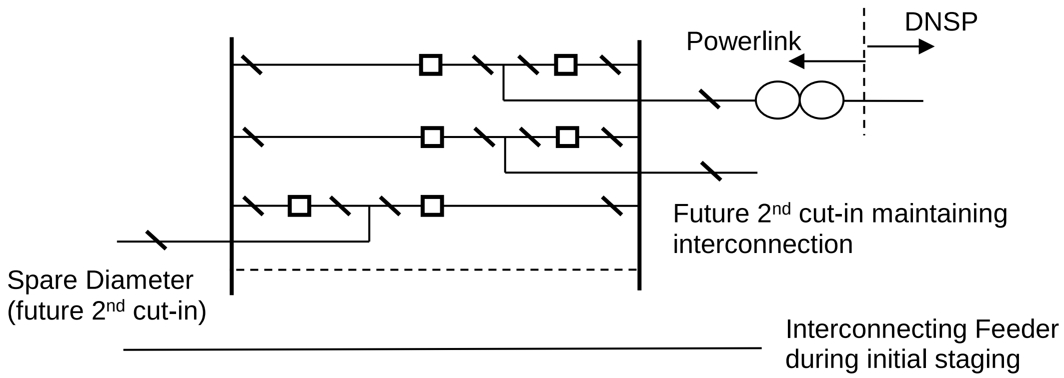

Figure 7: Breaker and a Half Layout (through-flow interconnection critical)

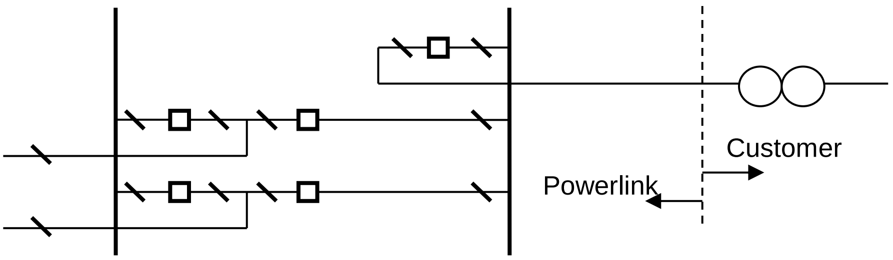

Figure 8: Breaker and a Half Layout (feeders from different sources with Customer connection)

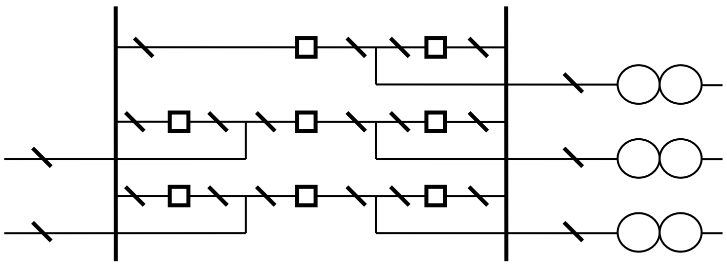

Figure 9: Breaker and a Half Layout (feeders from same source - more than 2 Transformers)

In some cases where the customer is willing to accept lower reliability and is still requesting to connect to 275kV and 330kV network, and where this arrangement will not compromise reliability of the regulated network, Powerlink will consider a meshed configuration. Figure 10(a) shows the minimum configuration for a single outgoing generator or feeder connection and figure 10(b) for a connection requiring two outgoing connections. These configurations are only acceptable when the generator/s connection involves cutting into a single 275 kV or 330 kV feeder only and will be subject to the endorsement of General Manager Network Operations and approval by Executive General Manager Delivery and Technical Solutions as its acceptability is dependent on the requirements for through flow. Ratings of equipment connected to the shared network will be specific for each configuration and will supersede the standard ratings as provided in Powerlink's document.

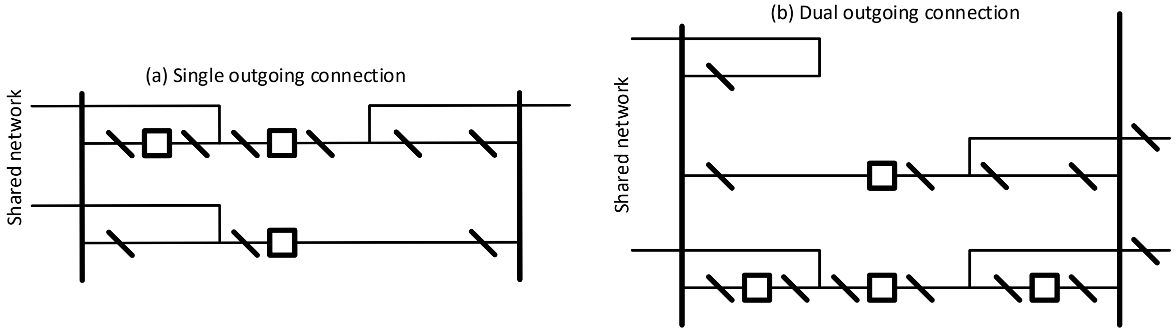

Figure 10: Meshed Configuration – single outgoing connection (left) and dual outgoing connection (right)

3.1.2 Less Critical Reliability Configuration

For substations where reliability is not as critical a "U bus" or folded bus configuration is preferred (see below). Bulk supply and small customer substations are examples of substations where a "U bus" configuration is preferable.

This category would include most 110kV and 132kV substations, except for those supplying major customer loads (separately negotiated).

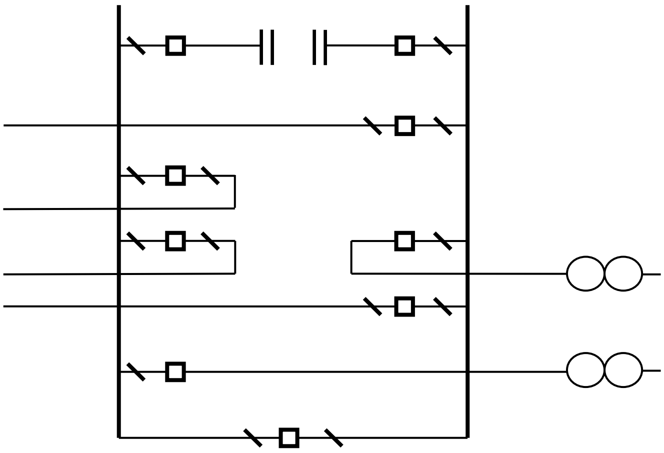

Figure 11: Typical U Bus Configuration (Folded Bus)

Where a third transformer (and/or third feeder where all three feeders are from the same source) is required for a highly reliable connection, it is to be made bus CB selectable (Figure 12). Where high reliability is not a requirement and will not have impact on the shared network, an alternative connection can be made by agreement.

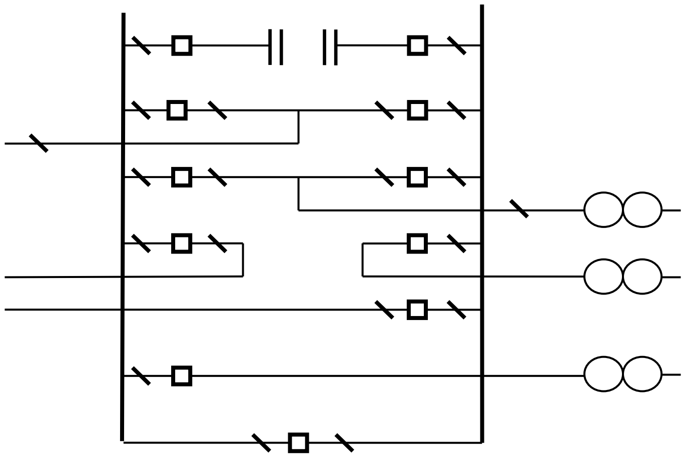

Figure 12: U Bus Layout (more than 2 feeders from the same source and/or more than 2 Transformers)

Minimum Configuration

The standard minimum connection for a non-bussed arrangement for up to two transformers is as shown in Figure 13. This arrangement is an interim configuration before developing into a bussed configuration as dictated by regulated or non-regulated drivers and can be applied to 110, 132, 275 and 330kV substations assuming that distance between circuit breaker and transformer is no longer than 30 km and the circuit breaker exist at the far end and there are LV transformer circuit breakers.

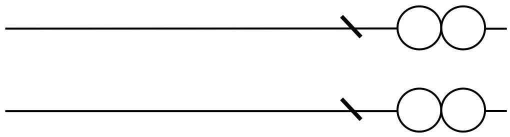

Figure 13: Transformer ended Layout (feeders from the same source)

The standard minimum connection for a prescribed (highly reliable), 2 feeder, 2 standard sized transformer connection (bussed) is for 5 CBs as shown in Figure 14. For negotiated customer connections 3CBs (to include feeder CBs) is acceptable where both feeders are from the same source as shown in Figure 15.

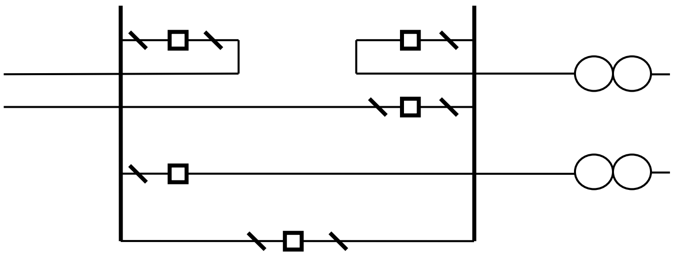

Figure 14: Simple U Bus Layout (feeders form different sources)

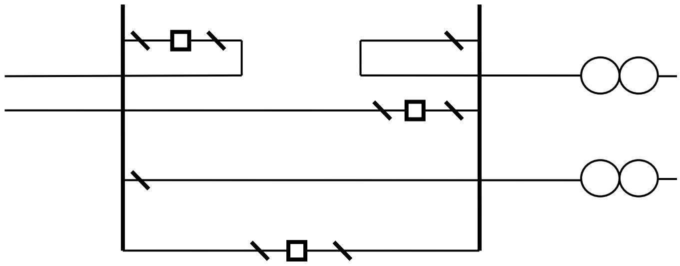

Figure 15: U Bus Layout (feeders from same source) with no transformer breakers

If the connection is to one of the older substations which already have isolator (disconnector) bus selectability this arrangement may be maintained only in the cases where a low impedance protection arrangement already exists. This arrangement is shown in Figure 16. Low impedance protection is more expensive so this arrangement is not the most economical solution. It also relies on auxiliary switch positions so it is less reliable and maintenance costs are increased.

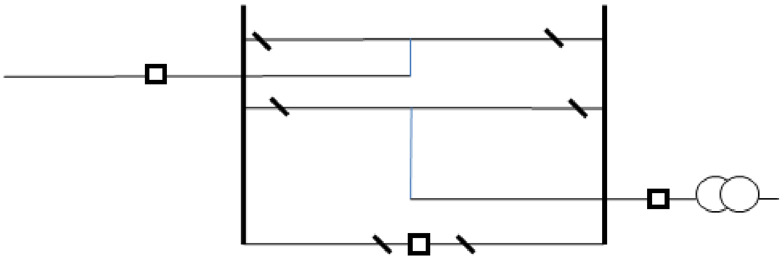

Figure 16: Isolator Selectable U Bus

3.2 Gas insulated Substations

3.2.1 High Reliability Configurations

Gas barriers shall be provided such that any faulty circuit breaker can be removed and replaced without having to interrupt the associated element (for example feeder or transformer) from service.

GIS substations required to supply loads which call for a high reliability and availability shall be laid out in a “breaker and a half” configuration, electrically configured as for AIS (see Figure 4). Substations serving major customers are examples that may require this busbar configuration. This arrangement allows flexibility for operation and maintenance however it is also the higher cost option due to the number of primary plant items.

This category includes main grid substations 275kV and above. Generally 110kV or 132kV substations would not fit this category though possible exceptions are the replacement of legacy substation at power stations or specific customer loads that require high-reliability (negotiated separately).

Minimum Configuration

For high reliability network requirements, connections are as per the AIS configurations of Figures 6 and 7. Where high reliability is not paramount, configuration shown on Figure 8 can be applied.

3.2.2 Less Critical Reliability Configuration

For substations where reliability is not as critical a “bus disconnector selectable” configuration is preferred (see Figure 17). Bulk supply and small customer substations are examples of substations where this configuration is preferable.

The isolator selectable configuration is preferred for GIS over the “U bus” as it allows continued operation of all circuit elements with a busbar out of service and removal and replacement of a faulty circuit breaker without disruption to other circuit elements.

This category includes 110kV and 132kV substations where GIS is an economic solution.

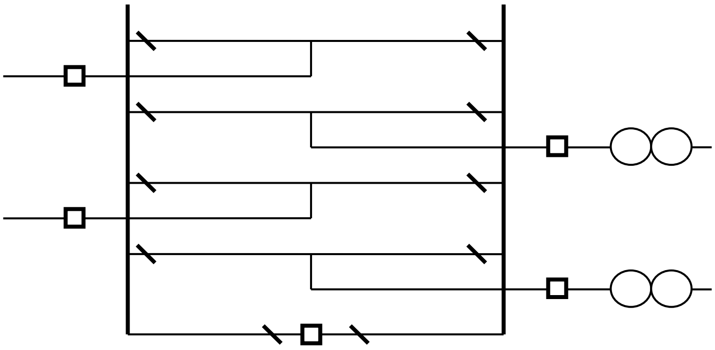

Figure 17: Typical Bus Disconnector Selectable Configuration

3.3 Alternative Technologies

Due to physical restrictions at some sites, alternative technologies from air insulated substations (AIS) will need to be considered. This version includes recommended busbar configurations for gas insulated substations (GIS). Additional considerations for GIS include positioning of gas barriers to ensure that any failed equipment components can be replaced with minimum disruption to remaining circuits and connections.

This busbar configuration framework is summarised in the following tables:

Table 1: General Policy

Voltage	Application	Recommended Configuration
275kV &330 kV	Main grid and major customers	Breaker and half for both AIS and GIS
132kV & 110kV	Sub-transmission	U–bus for AIS & bus disconnector selectable for AIS where low impedance protection exists Bus disconnector selectable for GIS

Table 2: Specific Case Exceptions

Voltage	Application	Recommended Configuration
275kV &330 kV	Lesser availability acceptable, customer typically.	Meshed configuration for AIS only
All voltage levels	Lesser availability acceptable, customer typically.	Transformer ended feeders.
All voltage levels.	Lesser availability acceptable, customer typically.	Teed feeder arrangement –can NOT be combined with transformer ended feeders.
132kV & 110kV	Customers that require high reliability	Breaker and half for both AIS and GIS