Distribution Point-of-Delivery Interconnection Process Guideline

Typical Supply Arrangements

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1.0 Introduction

1.1 Purpose

This guideline provides tools by which a Transmission Facility Owner (TFO) and Distribution Facility Owner (DFO) can evaluate supply arrangements for a new or existing Point of Delivery (POD) Substation. The intention is to provide a uniform and consistent approach for selecting appropriate arrangements at both the distribution and transmission level.

This guideline is intended solely for the purpose of supporting the AESO's customer interconnection process to arrive at proposed interconnection concepts that are optimized on a technical and economic basis. It will not in any way address or determine the AESO's facility cost allocation between system and customer, nor will it be used in any way as a guideline in applying the AESO approved tariffs and investment policy.

This guideline is intended to facilitate documentation of the project need and the evaluation done to support the need, in alignment with the interconnection process. The interconnection process has a requirement for AESO endorsement and AEUB approval of the project need.

1.2 Application of Guideline

This guideline applies to the addition of a new POD Substation or an existing POD Substation that is being upgraded.

This guideline contains numerical load values that are not to be considered as a "hard and fast" rule, but rather breakpoints that trigger examination of alternative supply arrangements.

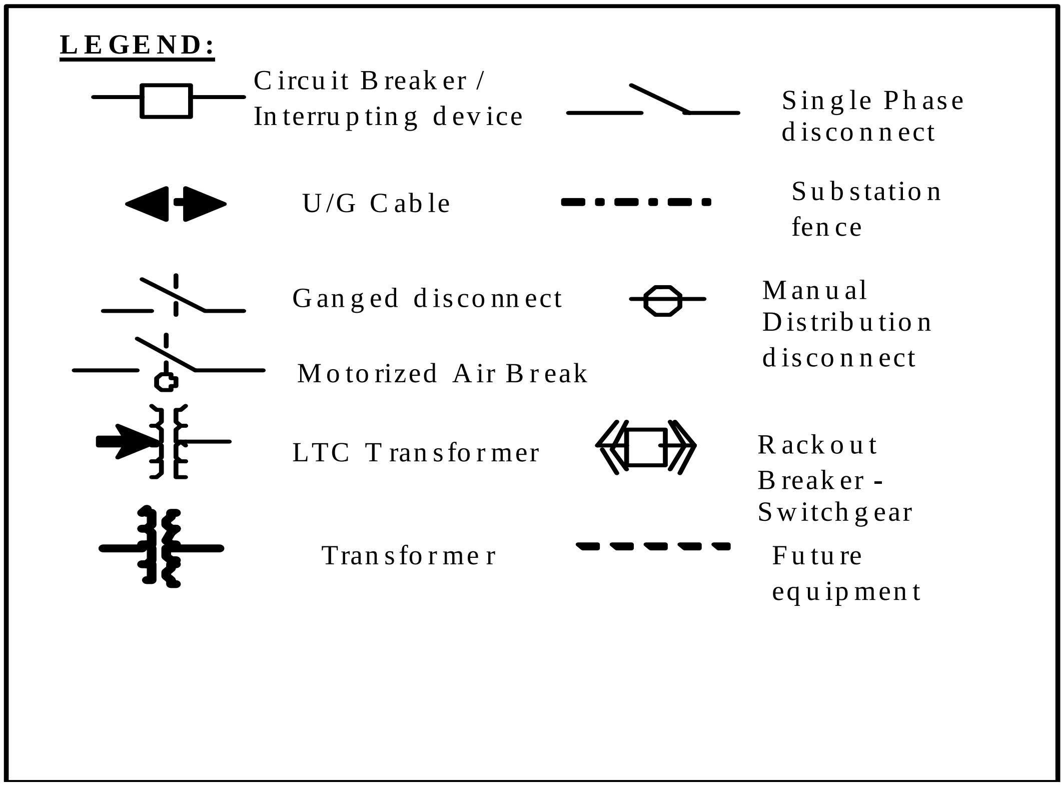
1.3 Modifications

In respect to this guideline the AESO will:

a) seek and consider the input and feedback of affected parties prior to making changes or additions to the guideline;
b) make and manage all changes to this guideline;
c) make this guideline publicly available via the AESO website;
d) periodically and within five (5) years of the effective date shown on the cover page review this guideline.

2.0 Symbol Legend

The symbols shown in the legend below are those that are used throughout the document.



3.0 Transmission – Radial/T-Tap Interconnection

Figure 3-1 illustrates typical Radial/T-Tap supply arrangements

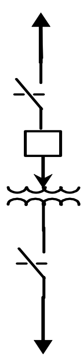


Figure 3-1 Radial/T-tap transmission station layout

3.1 Application of Supply Arrangement

The radial station layout is used for remote load stations or loads connected via a t-tap interconnection. The radial line station design has several considerations that determine the use of the arrangement. The considerations below are to be used in conjunction with the AESO Interconnection Guidelines – Standards of Service:

a) Sensitivity of load - Radial or t-tap connection is not recommended for urban (as defined in Standards of Service) connections due to the increased outage exposure and sensitivity of urban load.

b) If the load is expected to stay static or have minimal growth that will not exceed the 15 MVA load limit within 10 years, then a radial connection/t-tap interconnection should be considered. The 15 MVA trigger is a threshold value that has been used historically and is, in general, a level when other distribution and back-up concerns start to arise.

A breaker is used in place of circuit switcher for a radial station for high fault locations because circuit switchers generally do not have as high a fault rating as breakers.

The following should be considered, not as “hard and fast” rules, but rather breakpoints that trigger examination of alternative supply arrangements. T-tap connections should generally be limited such that there are:

a) A maximum of three fault current source connections (Transmission Network or Transmission Generator connections)
b) No more than one load connection that must be reasonably spaced between the three fault current sources.
c) No more than two load connections with two fault current source connections (Load to be limited to 30 MVA, maximum 15 MVA per T-tap)

More than one T-tap can be used on a radial extension provided adequate protection can be maintained and only one transmission source is available.

3.2 Characteristics of Supply Arrangement

a) Simplicity of design makes for a cost effective station for small dedicated loads or remote loads.
b) Reliability largely dependent on transmission line performance.
c) Lengthy outages occur for any problems forcing breaker, transformer or bus from service.
d) Bus fault will clear station.
e) The longer the tap the higher the exposure to line faults for the load
f) Location of tap can drive possible requirement for communication aided line protection, therefore adding to cost and complexity.

3.3 Expandability

The T-tap design may be built without expansion in mind as the station is small and compact in nature. If future expandability is not considered during original construction, expansion can be expensive and require very long outages and subsequent interruptions in service to customers.

A T-tap interconnection can allow for expansion by leaving enough space for the development of a simple bus. If these steps are taken the cost for expansion can be minimized.

4.0 Transmission – Sectionalizing Station

Figure 4-1 illustrates the typical arrangement of a sectionalizing station

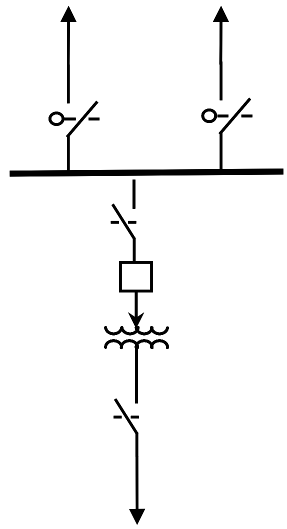


Figure 4-1 Sectionalizing transmission station layout

4.1 Application of Supply Arrangement

A sectionalizing station can perform the required sectionalizing via auto-sectionalizing scheme, SCADA assisted operator switched sectionalizing, or a combination of auto-sectionalizing with operator assisted backup. The sectionalizing station design has several considerations that determine the application of the arrangement. Its' design provides some enhanced levels of reliability to load over a radial or T-tap design described previously. The considerations below are to be used in conjunction with the AESO Interconnection Guidelines – Standards of Service:

a) If the load is expect to stay static or have minimal growth that will not exceed the 15 MVA load limit within 10 years then a sectionalizing design should be considered. The 15 MVA trigger is a threshold value that has been used historically and is, in general, a level when other distribution and back-up concerns start to arise.

b) Sensitivity of load – Sectionalizing station connection is not recommended for urban connections due to the increased outage exposure and sensitivity of urban load. However, if the load is sensitive to extended outages then a sectionalizing station provides better reliability than a radial line or T-tapped for sustained faults.

c) As a general rule, a sectionalizing station should only be used on a line that has an outage rate less than twice the 5-year system average, for that particular voltage class.

d) The distance from the station to the main line interconnection point. Consideration should be given to the distance of the additional line length compared to the length of the main line. The benefit from the sectionalizing scheme decreases as the length of exposed line increases.

4.2 Characteristics of Supply Arrangement

a) Basic design premised on future conversion to an in/out configuration.
b) Cost effective for smaller more sensitive loads if such loads are able to tolerate momentary line outages.
c) Station can be returned to service after a permanent fault on one of the interconnecting transmission lines.
d) Reliability is dependent on transmission line performance. The station outage rate will be dependent upon line outage rate.
e) Bus fault clears entire station
f) Station will suffer outages for momentary faults on the interconnection transmission line(s)

4.3 Expandability

As long as the space is provided for a future breaker installation, a sectionalizing design is typically set up to expand into an in/out bus design or a simple bus as described in Section 5.0.

5.0 Transmission - In/Out Station

Figure 5-1 illustrates the typical supply arrangement of a In/Out station.

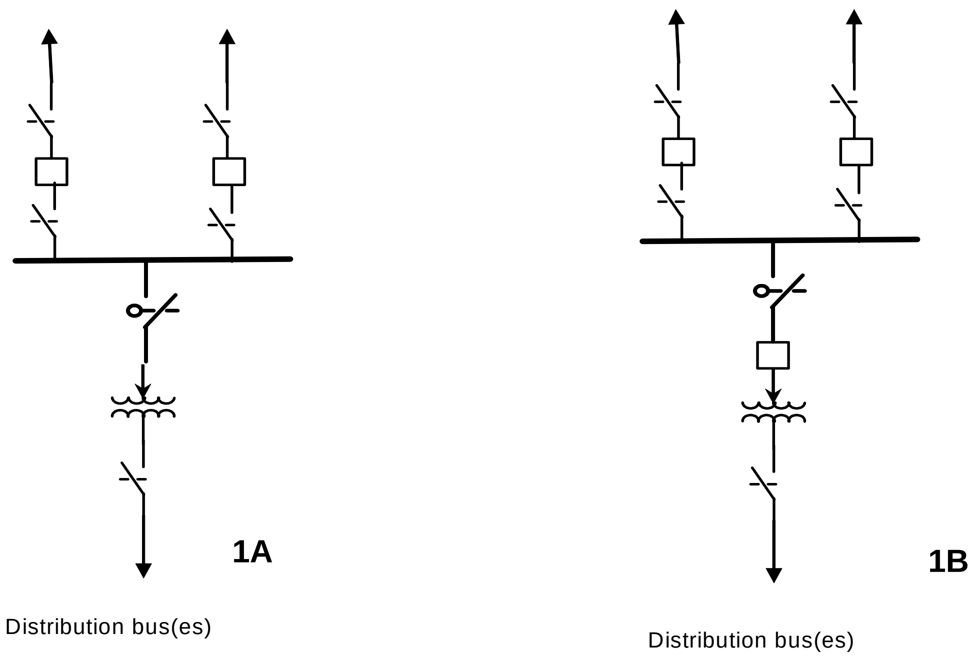


Figure 5-1A and 5-1B In/Out transmission station layout

5.1 Application of Supply Arrangement

The In/out Station design has several considerations that determine the application of the arrangement. The considerations below are to be used in conjunction with the AESO Interconnection Guidelines – Standards of Service:

a) When loading is greater than 15MVA or if the station load is expected to exceed 15 MVA in less than ten years an in/out arrangement should be considered. The 15 MVA trigger is a threshold value that has been used historically and is, in general, a level when other distribution and back-up concerns start to arise.

b) Sensitivity of load –This arrangement is usually the minimum requirement for urban connections due to the reduced outage exposure and sensitivity of urban load.

c) An In/Out station should be considered if the line used for interconnection is a poor performer (an outage rate more than twice the 5-year system average).

d) If the load is greater than 45 MVA and there are two transformers, this will trigger an examination of a more secure supply due to the increase load exposure and possible system implication for the loss of the entire line for a transformer loss. A consideration should be given to a high side transformer protection as in Figure 5-1B for multiple transformers and/or simple bus design.

e) The In/out station arrangement is intended for two transformers per secondary voltage level. Above this limit, a more secure design should be implemented with transformer high side interruption device and/or Simple bus arrangement.

f) In applying figure 1-A one should consider voltage impacts at adjacent PODs, interruptions to radial lines fed from the HV bus, capacitor banks on the high voltage bus, and phase angle issues with auto-reclose. This arrangement is not generally applied above 138 kV.

5.2 Characteristics of Supply Arrangement

a) Line faults do not disrupt the supply service compared to a radial or sectionalizing station.
b) Line side breaker maintenance does not require station outages if the transmission line is part of a looped system
c) Bus faults result in loss of entire station
d) This arrangement is intended for PODs that can be supplied from either source.
e) Unless a high side transformer isolation device is installed as in figure 5-1B, or a sectionalizing scheme is used, both transmission lines are out of service until the transformer is isolated following a transformer fault.

5.3 Expandability

As long as the land requirements are in place, an In/Out design is set up to expand into a simple bus design. The In/Out design can also be expanded into a ring bus or even a breaker-and-a-third if this is considered at the initial design. There is however, incremental work required at the start over a basic in/out design. If expansion beyond the simple bus is not planned, moving to a ring bus or breaker-and-a-third configuration can be land and resource intensive.

6.0 Transmission - Simple Bus Station

Figure 6-1 illustrates the typical arrangement of a simple bus station.

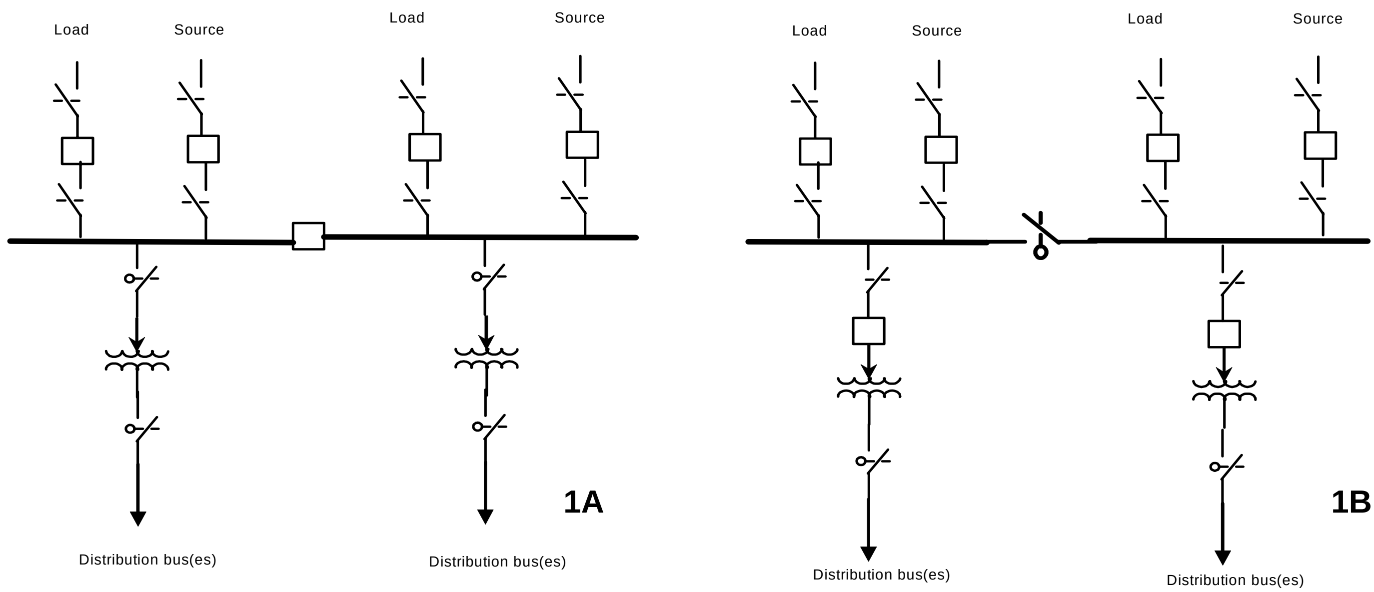


Figure 6-1A and 6-1B Simple Bus transmission station layout

6.1 Application of Supply Arrangement

The Simple bus design is the extension of the In/out design, with the emphasis on increasing the security of supply with multiple sources. This is a typical design for a station with multiple transformers or large transformer loads. The ultimate design should be limited to 4 or less transmission lines and/or 3 Load serving transformers and would generally be used where the load is greater than 45 MVA. This station should also be considered when the load size begins to influence area voltage levels and line loads. Adding additional transformers can be considered as long as the increased exposure of load is acceptable.

The installation of appropriate transformer high side current interrupting devices and/or bus tie breakers should be considered where there is more than one transformer.

Wherever possible the incoming lines are alternated load and source on the high side, to prevent the loss of a section of bus (when bus tie present) from causing the loss of all the load feeds or all the source feeds to a station.

6.2 Characteristics of Supply Arrangement

a) Line faults do not disrupt the substation service
b) Multiple sources increase security of station
c) Avoid lengthy and costly POD outages for transformer problems or maintenance (assuming redundancy in transformer capacity or distribution backup)
d) Bus faults, or transformer faults result in loss of the entire station unless a bus tie breaker, a transformer high side interrupting device, or a sectionalizing scheme is used (Figure 6-1B),
e) Loss of line ties during maintenance of tie breaker or switch.
f) Difficult to expand to breaker-and-a-third or breaker-and-a-half if not initially planned

6.3 Expandability

The simple bus design is the full expansion of the sectionalizing and in/out designs. An existing simple bus can be converted to a ring bus or Breaker-and-a-third if it was initially designed for; otherwise, the conversion can be very costly.

7.0 Ring Bus

Figure 7-1 illustrates the typical arrangement of a ring bus station.

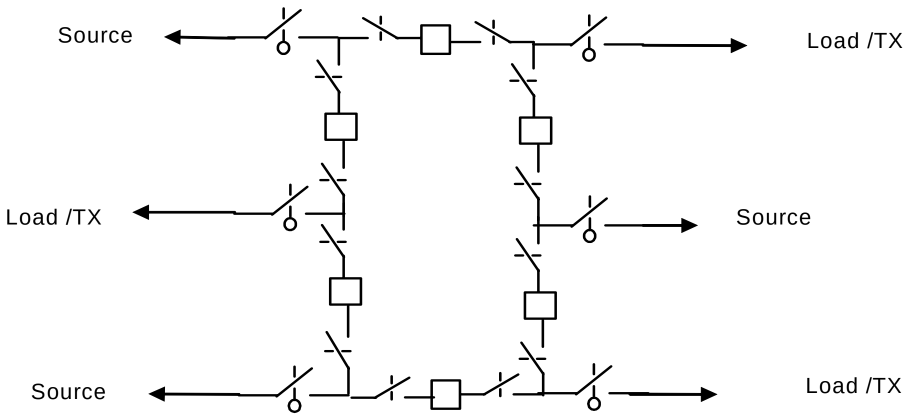


Figure 7-1 Ring Bus transmission station layout

7.1 Application of Supply Arrangement

The ring bus design provides for security of supply with multiple sources, no bus exposure, and has operating flexibility for planned and forced outages. This configuration is designed for stations with large transformer loads that require a high degree of reliability. The design should be limited to 6 or less transmission elements to prevent fragmentation concerns. Fragmentation concerns can manifest themselves in the form of segmentation of key parts of the network. This is a viable choice for applications where both system and load security and reliability are prime concerns.

7.2 Characteristics of Supply Arrangement

a) Large number of lines and loads no longer susceptible to bus faults or individual element failures
b) Allows for certain breaker and bus maintenance without disrupting important transmission system ties. Reduces stability or reliability concerns during station maintenance.
c) Cost effective with only 1 breaker per line/load interconnection.
d) Line faults do not disrupt the substation supply
e) Multiple sources increase security of station
f) A second contingency outage may cause fragmentation and/or loss of part of the station.

g) Entire station is not lost for a breaker failure situation
h) The ultimate number of elements to be built at the station must be defined at the initial design, otherwise expansion and integration of a new leg will be expensive and space consuming.

7.3 Expandability

The ring bus is easily expandable to its limit of 6 transmission elements and can be easily converted to a breaker-and-a-third if this was considered in the initial design. If conversion to a breaker–and-a-third was not considered then conversion may be more land and resource intensive.

8.0 Transmission - Breaker-and-a-Third station and Breaker-and-a-Half Station

Figure 8-1 illustrates the typical arrangement of a Breaker-and-a-Third and Breaker-and-a-Half station.

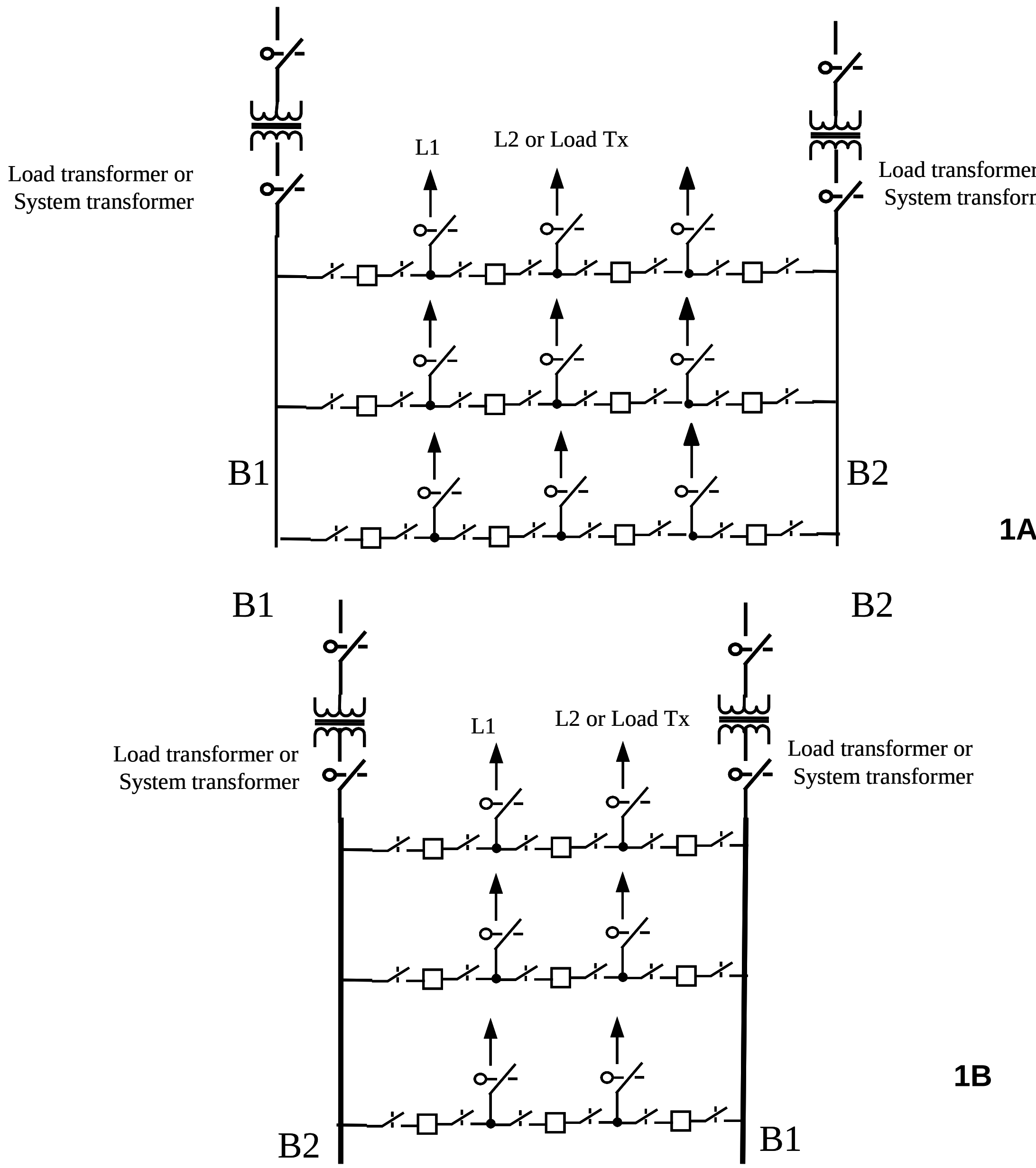


Figure 8-1A Breaker-and-a-third transmission station layout and Figure 8-1B Breaker–and-a-half transmission station layout

8.1 Application of Supply Arrangement

The Breaker-and-a-Third and Breaker-and-Half designs increase the security of supply with multiple sources, minimal bus exposure, and allowing for maintenance without supply outages. It is intended for stations where the primary function is an area hub, and/or large loads (100 MVA +), that are sensitive to loss of load for either momentary or sustained element outages. It can be considered when supplying large urban centers. The choice of the Breaker-and-a-Third or the Breaker–and-a-Half design will depend on the specific requirements of the situation.

The breaker-and-a-half design can be used in a distribution application for an urban environment. The AESO's Reliability Criteria should be reviewed and AESO planning should be consulted when considering applications of this arrangement.

8.2 Characteristics of Supply Arrangement

a) Higher reliability for maintaining system continuity for breaker fail, bus faults, or a contingency during breaker and or bus maintenance.
b) Multiple sources increase security of station and system reliability
c) Single point of failure will only remove one element from service. Breaker failure will result in the loss of only 2 elements
d) Allows for significant maintenance without outages
e) Expensive for load application only
f) Space intensive due to number of lines and design layout.

8.3 Expandability

The only limit to the expandability of a breaker-and-a-third and breaker–and-a-half design is the available land. A third, fourth and fifth leg can be added. However, once the fourth leg is added consideration should be given to the addition of a main bus tie breaker to prevent fragmentation.

9.0 Distribution Simple Bus – Distribution Station Bypass

Figure 9-1 illustrates the typical arrangement of a distribution station bypass.

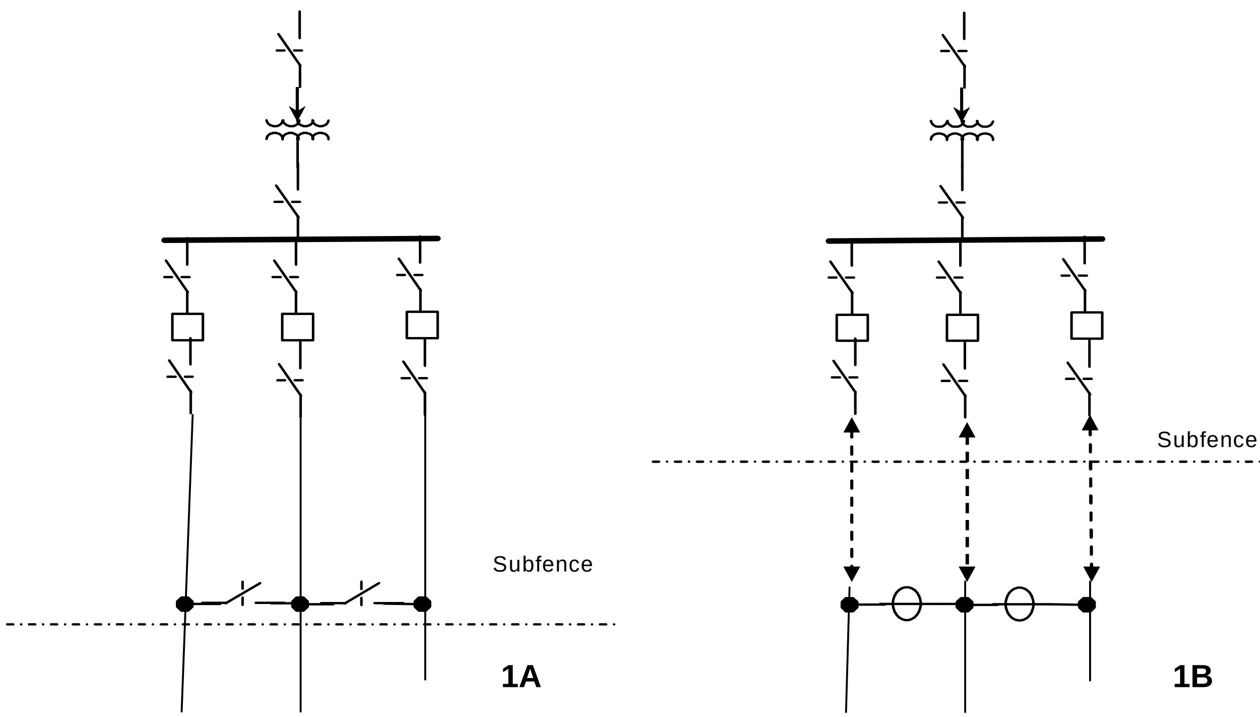


Figure 9-1A Simple Bus – Distribution Overhead station bypass and 9-1B Simple Bus – Distribution Underground station bypass

9.1 Application of Supply Arrangement

This is the typical distribution design for rural and a mixture of Urban and rural load. It is of limited use for an urban environment due to the extended switching times for service restoration. Either design is acceptable.

If feeder ties are made to other distribution buses it is recommended that, as a minimum, a motorized bus tie switch be used to allow remote operation and hence faster service restoration times. Ideally, a breaker should be used rather than a motorized switch.

9.2 Characteristics of Supply Arrangement

a) Distribution bypass allows for operational flexibility for maintenance
b) Allows for transformer maintenance and distribution bus work if a second transformer is present or a remote station back up is available.
c) Underground cable and overhead construction intended to meet N-1 needs for feeder backup
d) Switching time for manual devices is dependent upon switchman response for feeder restoration.

10.0 Distribution Simple Bus – Interior Station transfer Bus

Figure 10-1 illustrates the typical arrangement of a distribution station bypass.

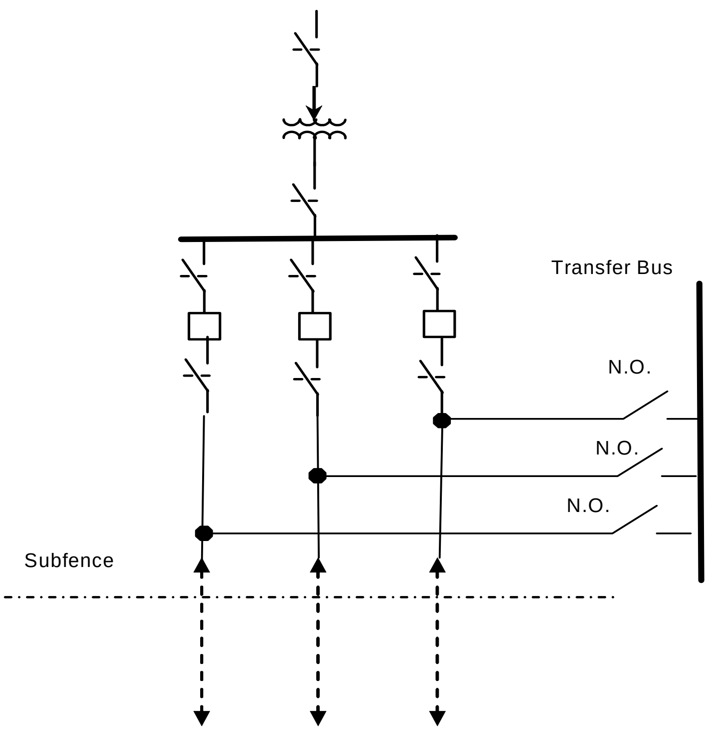


Figure 10-1 Simple Bus – Interior station bypass bus

10.1 Application of Supply Arrangement

This is an older distribution design for rural and a mixture of Urban and rural load. It is of limited use for a totally urban environment due to the extended switching time for restoration.

If a bus tie is made to another distribution bus it is recommended that as a minimum a motorized bus tie switch be used to allow remote operation and hence, faster service restoration times in the event of a loss of the transformer. Ideally, a breaker should be used rather than a motorized switch.

10.2 Characteristics of Supply Arrangement

a) Interior bypass allows for operational flexibility for maintenance
b) Allows for transformer maintenance if a second transformer is connected to the transfer bus
c) The transfer bus can not handle repair of the section from the breaker to the first switch outside the station.

11.0 Distribution Double Bus – Interior Station Bypass - Switchgear

Figure 11-1 illustrates the typical arrangement of an interior station Bypass Switchgear application.

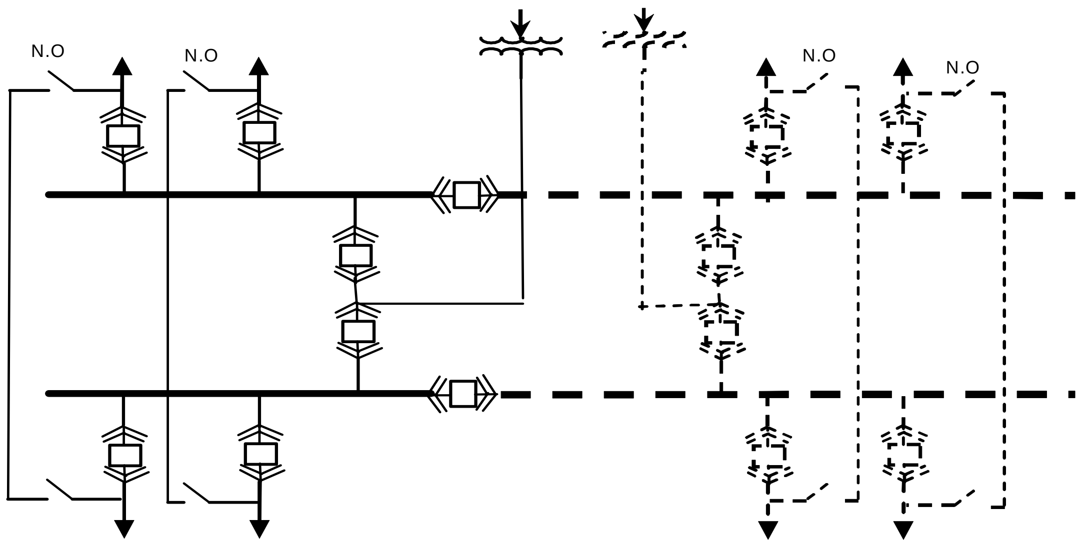


Figure 11-1 Double bus -Interior station bypass - Switchgear

11.1 Application of Supply Arrangement

This design is intended for an urban area as it provides the greatest operational flexibility and allows for possible automation. This design can be used in the development of a new urban substation and the ultimate development should be planned for initially. Because of the difficulty of obtaining land for future expansion, the ultimate substation site should be acquired initially.

11.2 Characteristics of Supply Arrangement

a) Significant operational flexibility
b) Automation capable
c) Expansion is accommodated
d) Bus faults or breaker fails affect a limited number of elements
e) Full feeder contingency transfer capable
f) Higher initial development cost to accommodate future expansion

g) Ultimate design needs to be planned for initially

12.0 Distribution – Dual secondary transformers with Breaker-and-a-Half

Figure 12-1 illustrates the typical arrangement of a dual secondary transformer with breaker and one half arrangements.

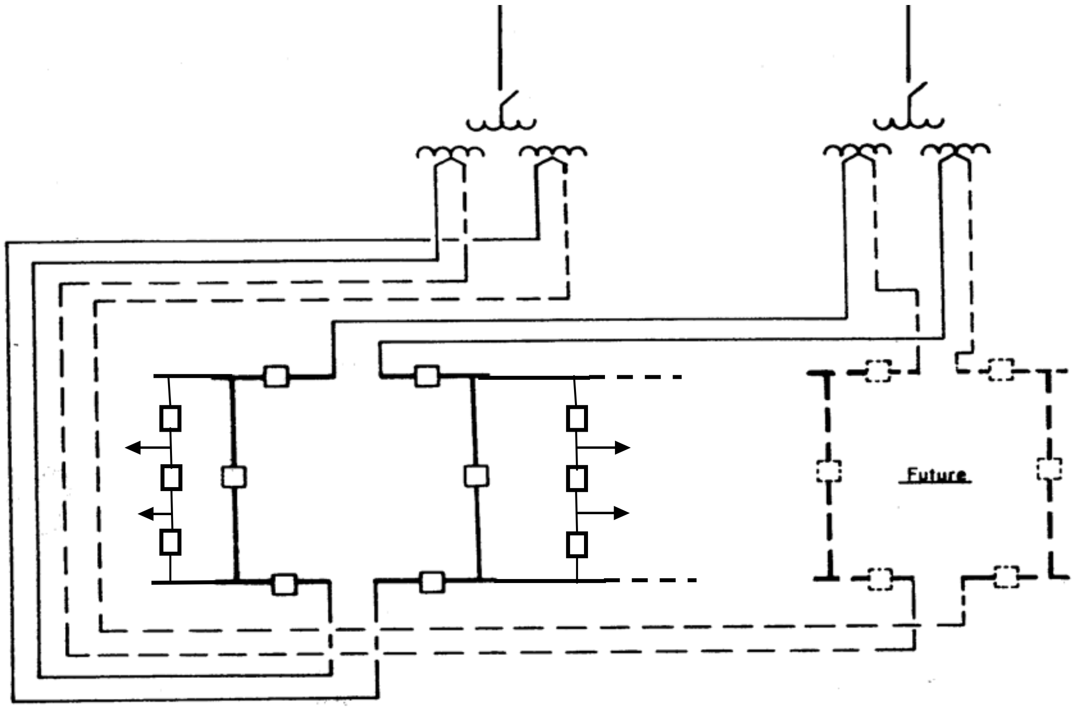


Figure 12-1 Double bus -Interior station bypass - Switchgear

The Breaker-and-a-half legs extend out to accommodate 8 feeders per leg to an ultimate of 16 breakers per three winding transformer. Total of 32 feeders to a station.

12.1 Application of Supply Arrangement

This design is intended for an urban area as it provides the operational flexibility and allows for possible automation. This design can be used in the development of an existing urban substation and the ultimate development should be planned for initially. Because of the difficulty of obtaining land for future expansion, the ultimate substation site should be acquired initially.

12.2 Characteristics of Supply Arrangement

a) Significant operational flexibility
b) Automation capable
c) Expansion is accommodated
d) Bus faults or breaker fails affect a limited number of elements
e) Higher initial development cost to accommodate future expansion
f) Ultimate design needs to be planned for initially