

III. Substation Bus Configurations and Substation Design Requirements

A. INTRODUCTION

There is some flexibility in developing a substation/switchyard arrangement for a particular interconnection. Pre-existing conditions, electrical arrangements or the criticality of the existing facility may limit this flexibility, but in the final analysis the interconnection arrangement must provide a high degree of reliability, operability and maintainability for the Transmission System. For these reasons, the breaker-and-a-half switchyard scheme is generally preferred for transmission switchyards and a line tap (particularly for high-voltage and extra-high-voltage lines) would not be considered acceptable. (Refer to PJM policies for additional guidance regarding three terminal line applications.)

There may also be instances when it is not considered prudent or practical to further extend an existing ring bus. Reasons for changing from a ring bus to a breaker-and-a-half arrangement might include the criticality or size of the load or generation to be interconnected, or the number of bus positions in existence or planned for the future. The larger the ring bus the greater the probability becomes during normal operations, multi-system events and maintenance that the substation could become fragmented into multiple pieces thereby losing its level of reliability.

~~The level of reliability for interconnected generation should be consistent with the generation's anticipated availability and frequency of operation. Multiple generators bussed onto a single line, for example may minimize transmission interconnection cost, but it could be at the risk of severe economic lost opportunity consequences for a single contingency failure.~~

B. FUNCTIONAL CRITERIA

When evaluating a proposed electrical interconnection ~~for new Interconnection Customer~~, physical as well as electrical characteristics must be considered. This can be done to a certain degree by evaluating the arrangement using the following criteria:

1. The clearing of failed ~~Interconnection Customer~~ Designated Entity-owned facility equipment, ~~including synchronizing breakers and Interconnection Customer transmission lines~~, should not adversely affect any other TO's facilities. ~~TO transmission circuits~~. This generally means that there could be one or more intertie breakers. ~~While this breaker need not be located at the POI, it should be the first element in the adjacent stations. No load, circuits, transformers, or other elements shall be tapped off the interconnection facility prior to its isolation.~~
2. The arrangement of circuits and breaker bays should be such that a stuck breaker operation will not trip two circuits on the same double circuit tower line.
3. Multiple ties should be provided between buses for all conditions, including all generation off line while at least one transmission line or station breaker is out of service for maintenance.
4. ~~The arrangement of lines and breakers owned by the Interconnection Customer and not under control of PJM shall not allow transmission network load current to flow through the Interconnection Customer facility interconnection equipment.~~
5. ~~For facilities without a generator terminal voltage synchronizing breaker or without transmission voltage intertie breakers, the generator radial attachment line should include motor operated line isolation switches to allow transmission bus ties to be established when a generator is off line.~~

Comment [CDT1]: Not sure if this applies, but if a DE is connecting Non-transmission (i.e. generation and distribution/load) facilities it may need to be addressed by our DE standards.

Comment [CDT2]: Not sure this applies to DE interconnections.

6. A transmission voltage line conductor or a static wire that drops within the switchyard area should not cause another transmission voltage circuit to trip. This means that there should be no line crossings within the switchyard fence and there should be adequate spacing between bays to minimize the possibility of a falling wire contacting another line's phase conductor.
7. Electrical equipment must be adequately spaced to:
 - facilitate equipment replacement
 - facilitate maintenance activities and associated maintenance equipment
 - minimize the likelihood that catastrophic failure of an item of equipment will adversely impact adjacent equipment.
8. The electrical arrangement of interconnections should be balanced throughout the arrangement. For example generation interconnections should be spread along the bus rather than grouped together at one end. The objective is to facilitate better load flow and balance throughout the substation facility. The connection of circuits and transformer into the station should be arranged to balance flows throughout the station bus. This can be accomplished by connecting elements anticipated to inject flow with those anticipated to supply load from the station. The objective is to balance flows in the station to reduce bus loading.
9. In addition to these evaluation criteria the following factors must be reviewed and weighed appropriately in performing the assessment of a substation configuration:
 - Operational complexity and flexibility
 - Reliability for the load
 - Reliability for transmission lines
 - Component reliability
 - Generator interface
 - Line Maintenance
 - NERC, MAAC requirements/criteria
 - Expandability/Adaptability
 - Safety
 - Changes in technology
 - Cost (capital and O&M)
 - Availability of spare equipment

Comment [CDT3]: The example speaks to injection from Generation. We may want to provide a more generic wording more fitting any type of Designate Entity facility.

C. SUBSTATION ARRANGEMENT

1. ACCESSIBILITY AND LAYOUT

- Adequate space and firm vehicular surface must be provided on at least one side of each item of major electrical equipment to permit O&M vehicles, including bucket trucks and cranes, to access electrical equipment and to maneuver without requiring the de-energization of any adjacent electrical equipment in order to conduct maintenance or to remove and replace equipment. In a breaker bay this access must be provided the full length of the bay and must not be encumbered by overhead electrical equipment or conductors. Appropriate stone or asphalt roadway must be provided. Typical breaker bay centerline to adjacent bay breaker centerline distances is 65' for 230kV and 110' for 500kV. For indoor GIS equipment a bridge crane may be used in lieu of roadways as long as this approach provides a feasible means to conduct maintenance including the removal and replacement of all major equipment.

- Electrical equipment must be arranged with adequate clearance for maintenance activities and for associated maintenance equipment, such that only the equipment to be maintained, including its isolating devices, needs to be operated and/or de-energized for the maintenance work to be performed. Each Transmission lines and Transformer must be equipped with a switch to isolate it from the substation such that the station bay or ring bus can be re-energized during maintenance of that Transmission lines or Transformer.
- Electrical equipment must be arranged with adequate clearances such that a catastrophic failure of equipment associated with one circuit would be unlikely to adversely affect equipment associated with another circuit.
- A corridor, typically 15 – 25 feet in width, must be provided around the inside perimeter of the substation for vehicle movement. The corridor must be adequate for the weight of vehicles transporting the heaviest item of electrical equipment installed in the substation. If the corridor is required to be paved, it must meet this same functional requirement and might typically be constructed with a 6” crushed stone base covered with 4” of asphalt, which is covered with a 2” top layer of cover asphalt.
- Twenty-four hours, unobstructed access must be provided for the substation. Typically asphalt paving is required from the driveway entrance to the relay/control house with parking for several vehicles. The entrance gate must be double roadway width with the yard’s safety grounding covering the open gate area.
- The switchyard should be appropriately graded to facilitate water runoff and to direct spilled dielectric fluid away from other major electrical equipment and toward planned containment.

2. GROUNDING AND FENCE

- A minimum thickness of appropriate stone must be provided for the entire substation site (except where paved), including over the perimeter fence grounding, consistent with the substation’s grounding design for step and touch potential.
- Grounding must be provided for the entire fenced site including the perimeter grounding outside the substation fence.

3. LIGHTING

- Adequate lighting must be provided throughout the substation to facilitate the manual operation of electrical equipment at night and perimeter security lighting should be provided.
- High mast lighting poles that could possibly fall across electrical equipment may not be employed.

4. LIGHTNING/SURGE/NOISE PROTECTION

- Lightning protection must be provided for all electrical equipment in the form of static wires and lightning bayonets. Static wires must run parallel to breaker bays to minimize the likelihood that a fallen static wire would adversely impact an adjacent bay. See V.N for details of required lightning shielding and Section II Design Criteria for performance requirements.
- Control wire shielding must be provided as appropriate and grounded as appropriate for substations with 230kV and above voltages.

Comment [CDT4]: Need to add Lighting requirement for 69-138kV and 765kV to Section II.

Comment [CDT5]: Do we want to expand this to lower voltages?

5. RACEWAYS

- Typical outdoor main raceway systems consists of pre-cast trench raceway installed either on grade or below grade with durable fire-resistant covers. Where vehicles must cross raceways, such as a driveway near the relay/control house, suitable covers and construction must be provided for the heaviest vehicle and equipment anticipated to cross the raceway.
- Physical separation of wiring associated with battery one from battery two associated wiring must be maintained in the raceway system.
- All wiring and raceway corridors must be at grade or below grade. Conduit and cable tray may not be routed in a plane at or above the height of electrical equipment. This requirement is intended to minimize the exposure of wiring to fire or explosion associated with electrical equipment.
- Raceways must be routed perpendicular to the main busses and must not be routed parallel and underneath high-voltage transmission lines.

6. SECURITY

- At minimum Locks are required for all gates and all doors and shall be compatible with the Transmission Owner's security system. If an electronic security system is provided there must be provisions for manual entry in the event of loss of power supply. All regulatory requirements shall be complied with.
- An intrusion alarm system shall be provided as appropriate and compatible with the Transmission Owner's security system.

7. RELAY/CONTROL HOUSE

- A substation relay/control house must be provided and should be located as centrally as practical to minimize circuit length to electrical equipment. The relay/control house should be located outside of the energized electrical infrastructure such that established roadway access to the house does not require going under an energized main bus. ~~If the Transmission Owner approves that t~~The roadway may go under overhead lines, the clearances must at least meet industry's overhead line roadway clearances.
- The relay/control house must be constructed for long life and minimum maintenance. ~~The local transmission owner must be contacted for specific design requirements, including the need for lavatory facilities and HVAC should be provided as required to assure equipment and batteries are kept with acceptable environmental conditions and for approved construction materials. The need for Lavatory facilities should be considered particularly if the facility is in a remote location.~~
- There must be an established demarcation in the relay/control house for leased telecommunication services and phones for the dedicated use of the Transmission Owner. These facilities must be independent of the Interconnection Customer's facilities.

8. AUXILIARY FACILITIES

Layout of the substation must take into account auxiliary facilities such as space, as appropriate, for an engine-generator set, maintenance facilities, lay down, pad and chain rail for bottle storage, etc.