ISO Rule 502.11 (Substations)

Industry Workgroup Meeting

December 17, 2015

Substation Bus Layout

- Layout is the physical arrangement of various elements and components relative to each another
- Layout influences the initial and future cost, reliability, O&M flexibility, and protection complexity
- Layout is driven by a number of factors
  - Reliability – Time and effort required to restore service
  - Cost
  - Switching flexibility in normal abnormal operating conditions
  - Space constraint
  - Expandability
  - Protection complexity of primary and backup protection systems

Substation Bus Layout

A good bus layout should

- support and promote safety and reliability of supply
- provide maximum maintenance and operating flexibility and
- be cost effective for current needs and future expansions

Substation Bus Layout

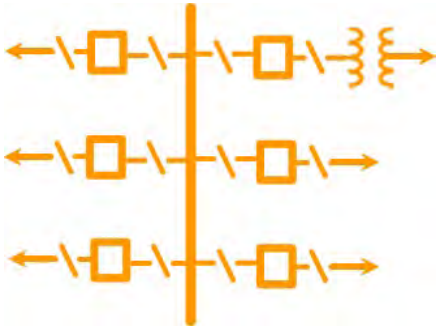
- Single bus (or sectionalized buses) in most existing 138/144 kV substations
- Double-breaker (some existing 240 substations, e.g., 205S, 102S)
- Breaker-and-half (>50% of new 240 substations)
- Breaker-and-third (some new 138 kV substations)
- Ring bus (some 240/144 kV existing substations, e.g., 732S, 809S, 856S)
- Other combinations

Bus layout	Approx. cost
Single bus	100%
Sectionalized bus	120%
Breaker-and-third	140%
Breaker-and-half	160%
Double breaker	210%
Ring bus	155%

Simple Bus

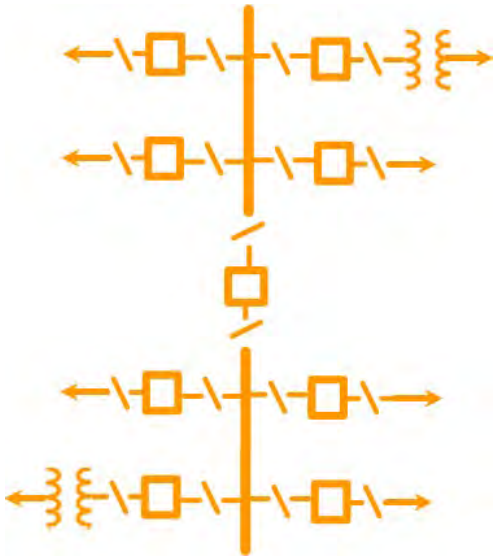
Advantages

- Lowest cost
- Small land footprint
- Simple protection

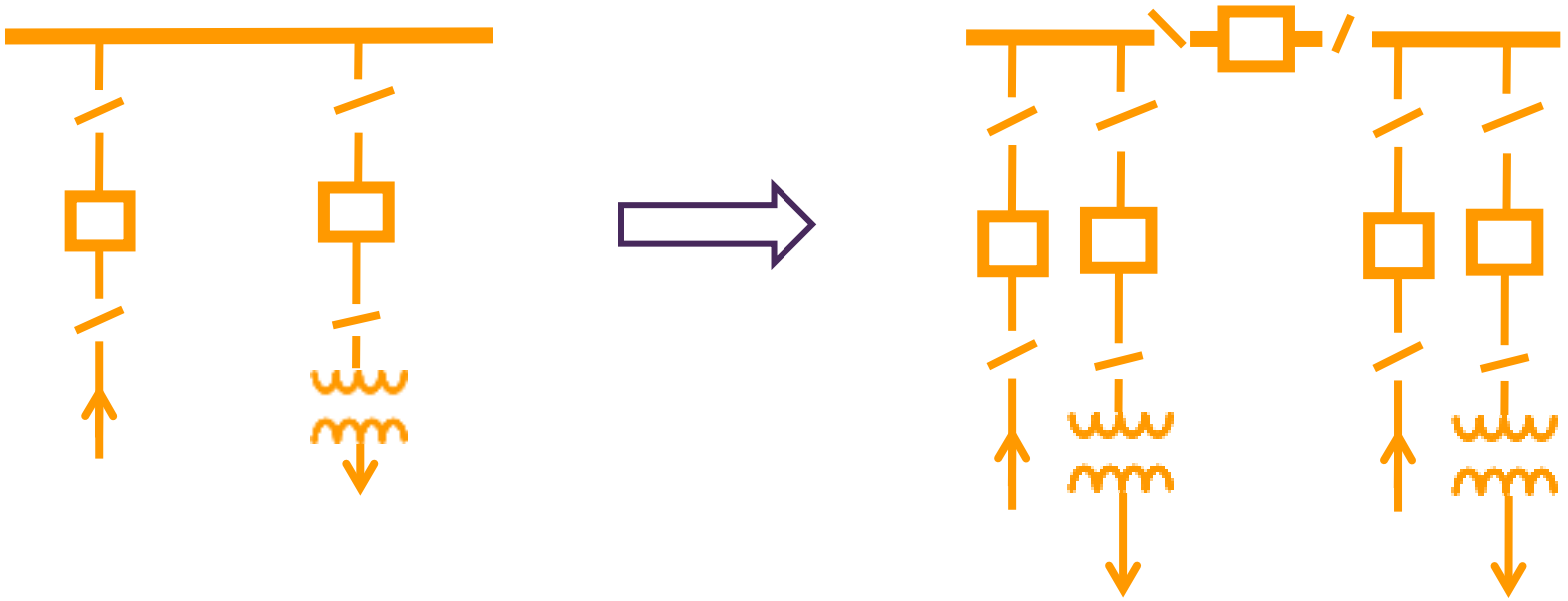


Disadvantages

- Lowest reliability – loss of entire station
- Loss of all circuits in a bus section
- Operating & maintenance flexibility



Simple Bus



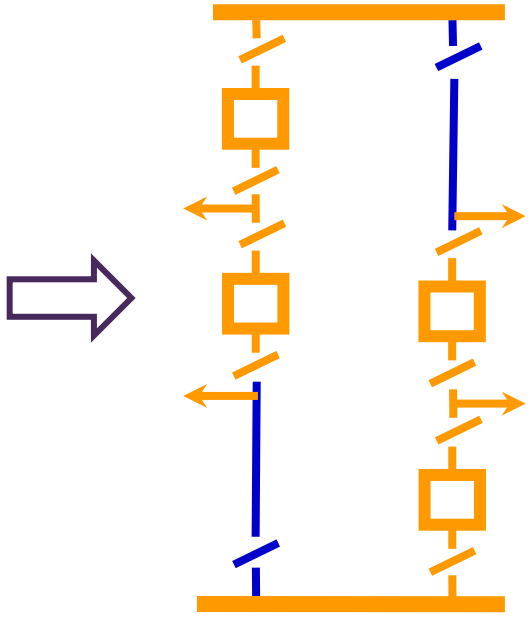
For all substations (for discussions)

- Under what conditions do we require sectionalizer? ≥ 2 incoming line terminations plus ≥ 2 transformer terminations?
- Under what conditions do we need a tie breaker? ≥ 3 line terminations?
- How do we consider expandability? Simple bus → breaker-and-half
- Should we require a breaker on the HV side of a power transformer? 502.3 requires dual high-speed protection for transformers with ≥ 25 MVA

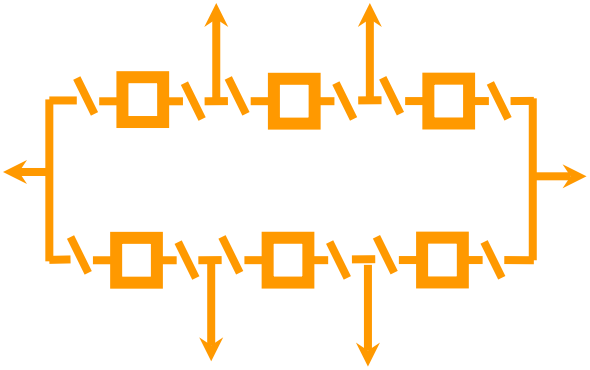
Substation Bus Layout

For all substations (for discussions)

- Bus layout will be such that it minimizes line crossings Yes ☐ No ☐
- A faulted **element** must not result in the loss of two or more of other **elements** Yes ☐ No ☐
- No additional **elements** be taken out of service to accommodate the maintenance of an **element** Yes ☐ No ☐
- No terminal components shall be the limiting factor for the rating of all **transmission facilities** connected Yes ☐ No ☐
- When constructing an incomplete breaker-and-half or breaker-and-third diameter, disconnect switches should be installed to minimize outage time during the installation of the remaining breakers Yes ☐ No ☐



Ring Bus



Advantages

- Higher reliability
- No main buses
- O&M flexibility
- Expandable to breaker-and-half (if initial design considers expandability)

Disadvantages

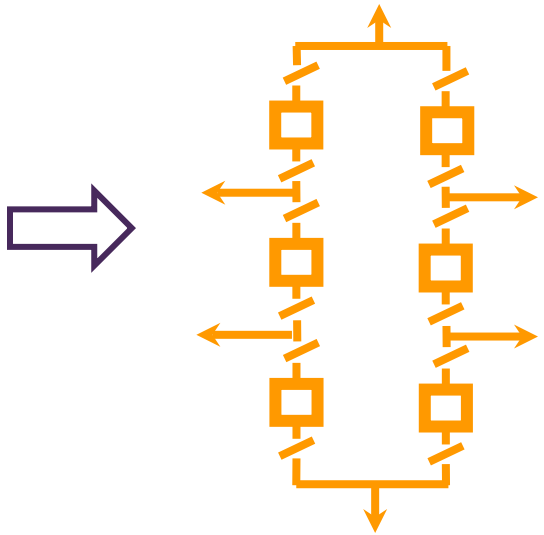
- System split under N-1-1 situations
- Protection complex (autoreclose)
- Number of PTs

Substation Bus Layout

For all substations (for discussions)

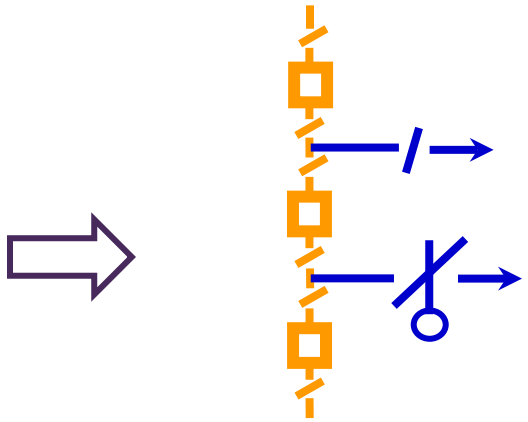
- A ring configuration is acceptable with up to six (6) breakers. A ring bus with more than six breakers is acceptable only if there are two or more transformer terminations

  Yes ☐ No ☐



- A disconnect switch at the line side must be installed for each transmission line, power transformer and/or generator connection to the substation

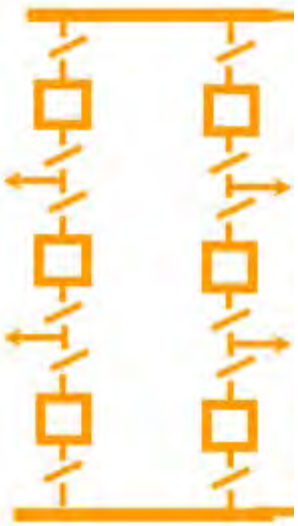
  Yes ☐ No ☐



Breaker-and-Half and Breaker-and-Third

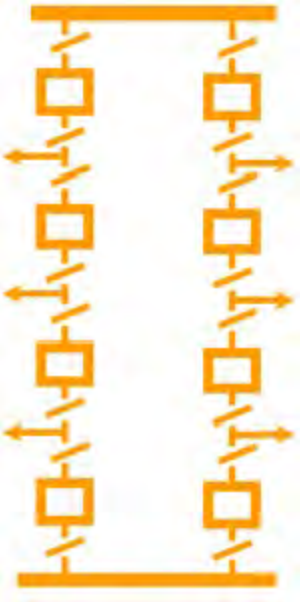
Advantages

- Highest reliability
- O&M flexibility



Disadvantages

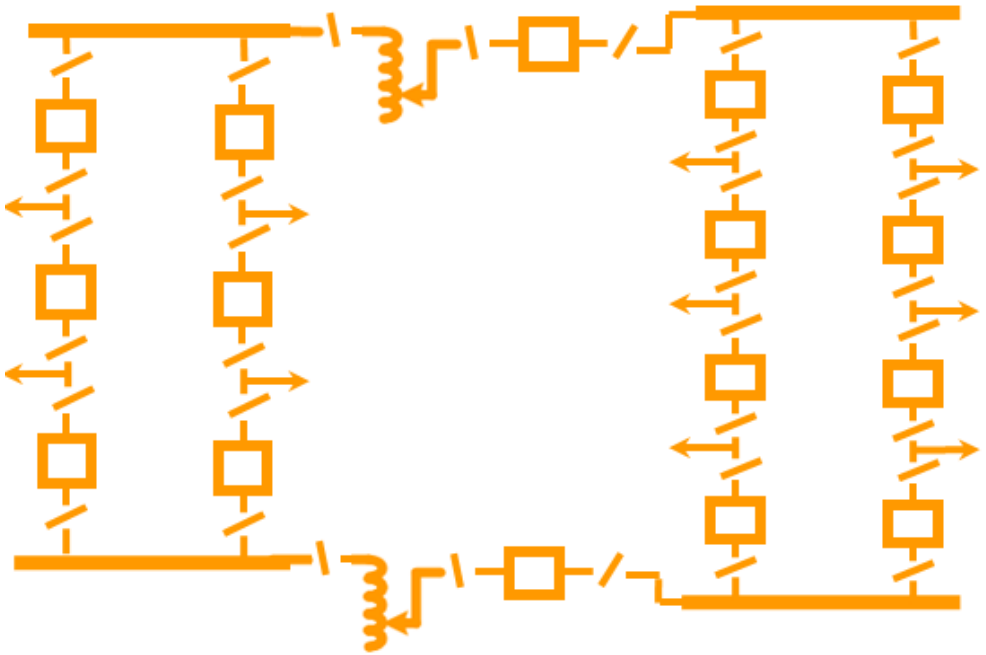
- Cost
- Complex protection
- Number of PTs



Breaker-and-Half and Breaker-and-Third

For discussions

- When do we need a breaker in series of the transformer?
  (three voltage levels?)
- Where should the breaker be?
  (it depends)



- Should we require that lines connecting to the same remote substation cannot be terminated to the same diameter?
  (e.g., double circuit lines between two substations)

Substation Bus Layout

Minimum bus ampacity requirement (A) (for discussions)

Component	138/144 kV	240/260 kV	500 kV
Main bus[1]	1200	2000	4500
Cross Bus[2]	600	2000	4000
Feeder[3] or Line terminal[4]	600	2000	3000

1 includes all sections of a ring bus scheme, or each bus section of a simple bus, a breaker-and-half or a breaker-and-third scheme

2 includes diameter sections of breaker-and-half or breaker-and-third schemes

3 includes all equipment from the connection at the low voltage bus to the riser pole

4 includes all equipment and conductor from the transmission line to the line breakers

Substation Bus Layout

For Type 1 Substations (for discussions)

- Each **element** must be separated by at least one circuit breaker
  Yes ☐ No ☐
- A fault within a bus section cannot result in the loss of another bus section
  Yes ☐ No ☐
- A faulted **element** must not result in the loss of any other **element**
  Yes ☐ No ☐
- Where all three voltage levels (500/240/138 kV) exist, breakers shall be installed between adjacent buses of different voltages
  Yes ☐ No ☐
- Extendibility or expandability – where a substation is initially designed with a simple bus or ring bus, but will ultimately be a 1.5 or 1.3 breakers, it is required that the initial layout must be such that it can be converted into the ultimate layout with minimal incremental cost and minimal disruption
  Yes ☐ No ☐

Substation Bus Layout

For Type 1 Substations (for discussions)

- In ring bus, the substation must be physically and electrically designed so that lines are not terminated in positions that will ultimately be evolved into buses. Transformers, however, are permissible to terminate in these positions

  Yes ☐ No ☐

- AESO shall provide, in the FS document, the ultimate substation configuration including the number of terminations and voltage compensation devices

  Yes ☐ No ☐

Substation Bus Layout

Any other points ?

Power Transformers

For discussions

- All transformers should be designed for an in service operating life that is comparable to other electrical apparatus in the same substation

  Yes ☐ No ☐

- Single phase vs. three phase – Should we require single phase transformers for circumstances such as
  - The GSU units at very large base load power plants (>800 MW or other values)

    Yes ☐ No ☐
  - 500/240 kV autotransformers with >800 MVA (or other value)

    Yes ☐ No ☐

Power Transformers

Over Voltage Protection (for discussions)

- All power transformer terminals shall be equipped with surge arresters with adequate protective margins

  Yes ☐ No ☐

- All surge arresters should be installed as close as possible to the transformer bushings

  Yes ☐ No ☐

Power Transformers

Rating and cooling (for discussions)

- Should we specify how transformers rating is determined for normal operation?

  Yes ☐ No ☐

- Should we specify overloading capability for large power transformers (like >1000 MVA)? The AESO has been specifying 30-minutes and 3.5-hours overloading capability for large transformers with >1,000 MVA

  Yes ☐ No ☐

- Should we require 55^{o}C rise (instead of 55/65^{o}C or 65^{o}C) for certain sized transformers?

  Yes ☐ No ☐

- Should we require “Full Capacity Below Normal” for all 240/138 and 500/240 kV autotransformers?

  Yes ☐ No ☐

Power Transformers

Tap changer (for discussions)

- Should we require OLTC on any power transformers (except GSUs and 500 kV transformers)?
  Yes ☐ No ☐
- Should we preclude the use of De-Energized Tap Changing for certain transformers?
  Yes ☐ No ☐
- Should we require LTC be always placed at the primary winding (or the wye winding)?
  Yes ☐ No ☐
- Tap range – should we require minimum number of steps and the range, or power factor range?
  Yes ☐ No ☐

Power Transformers

Impedance and losses (for discussions)

- Should we require a transformer loss study be conducted for all 500 kV or other voltage level transformers?
  Yes ☐ No ☐
- Should we specify an acceptable range of impedance?
  Yes ☐ No ☐
- Should we require that no-load loss, load loss and auxiliary loss must be all considered when conducting loss studies?
  Yes ☐ No ☐
- Should we mention IEEE Standard C57.120 as the transformer loss evaluation method?
  Yes ☐ No ☐

Power Transformers

Short circuit withstand (for discussions)

- Should we specify that “transformers shall withstand, without damage, the mechanical and thermal stresses by external faults”?
  Yes ☐ No ☐
- Should we specify at least 2 seconds for short circuit duration?
  Yes ☐ No ☐

Parallel operation

- Under what conditions do we allow parallel operation of transformers in a substation?

GMD and GIC

- Do we need any special requirements for geomagnetical disturbance?

Shunt Capacitor Bank

For discussions

- Under what condition do we require a shunt capacitor to be connected to a diameter between buses?
- Shunt capacitor banks must be solidly grounded with the neutral grounded at a single point
- For multiple parallel capacitor banks which are switched back-to-back, each bank shall have a circuit breaker
- H-coupled capacitor banks must have unbalance protection, both alarm and trip function
- Should we require that a TRV study be done for each project having capacitor bank(s) to determine the use of series reactors or other schemes (such as pre-insertion resistors) to limit the switching transient overvoltage and resonance?
- Any other points from WG members?

Shunt Reactor Bank

For discussions

- For line connected shunt reactors – Should we prescribe minimum compensation level?
- Should we limit the construction types of reactors to either gapped core type or magnetically shielded air core having fixed impedance?
- Should we require reactor to have constant impedance up to, say, 1.5 times the rated voltage?
- Under what condition do we require a shunt reactor to be connected to a bus or a tertiary winding?
- For line connected shunt reactors – Auto reclosing of a transmission line with line shunt reactors is prohibited unless it can be assured that the fault is in the line section
- For line connected shunt reactors – Shunt reactors must be either solidly grounded or grounded through a neutral reactor
- For line connected shunt reactors – Under what condition do we require a four legged reactor (if not four legged reactor, a separate neutral reactor)?
- For tertiary winding connected reactors – There must be a circuit breaker connected
- Any other points from WG members?