Substation Engineering
Lecture 12: Busbars (Part 2 of 2)

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Advanced Busbar Configurations

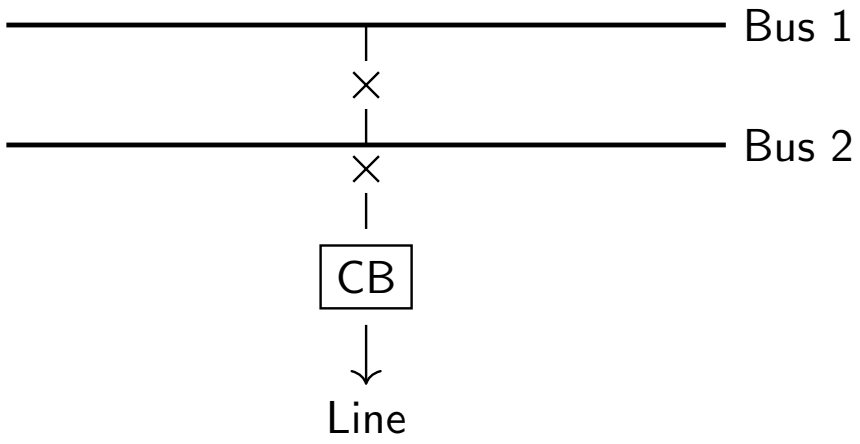
- Substation Engineering (DI04009011)
- Lecture 12: Busbars (Part 2 of 2)
- High-Reliability Systems for Transmission Substations

Agenda

- Recap of Reliability Challenges
- Double Busbar Single Breaker System
- Double Busbar Double Breaker System
- One-and-a-Half Breaker System
- Ring Bus (Mesh) System
- Comparison and Selection Guidelines

Double Busbar Single Breaker System

- Consists of two identical main busbars (Bus 1 and Bus 2).
- Each incoming/outgoing circuit is equipped with one circuit breaker but can be connected to EITHER Bus 1 or Bus 2 via isolators.
- A Bus Coupler breaker connects Bus 1 and Bus 2.
- Provides excellent flexibility: circuits can be divided between the two buses.

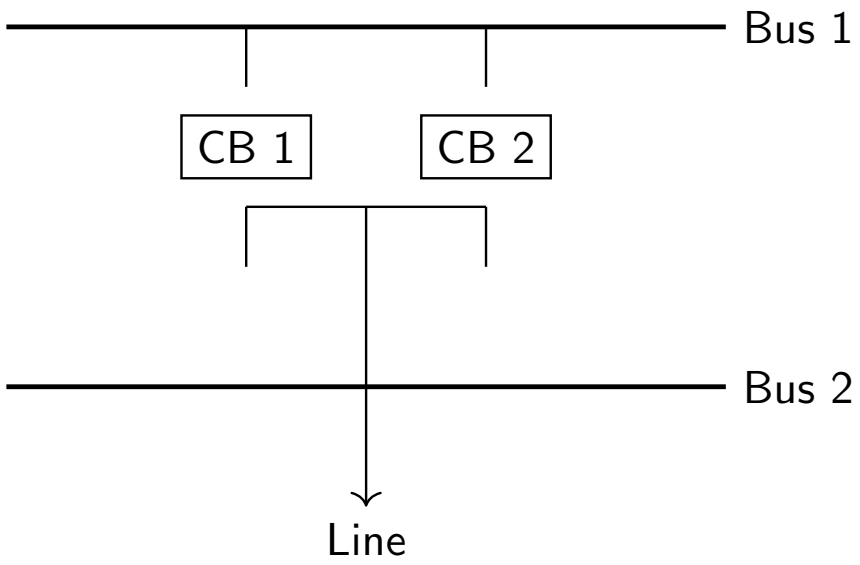


Double Bus Single Breaker: Operation

- Bus Maintenance: To maintain Bus 1, all circuits are transferred to Bus 2 without interrupting supply.
- Fault Isolation: A fault on one bus does not cause a total station outage.
- Limitation: Breaker maintenance still requires the connected line to be taken out of service, UNLESS a transfer bus is also added (Double Main & Transfer).
- Complex interlocking is required to prevent selecting both buses simultaneously under load without the bus coupler closed.

Double Bus Double Breaker System

- Two main buses, and TWO circuit breakers per circuit.
- Highest possible reliability: each circuit is permanently connected to both Bus 1 and Bus 2.
- Any bus can be cleared for maintenance at any time.
- Any circuit breaker can be maintained without taking the line out of service.

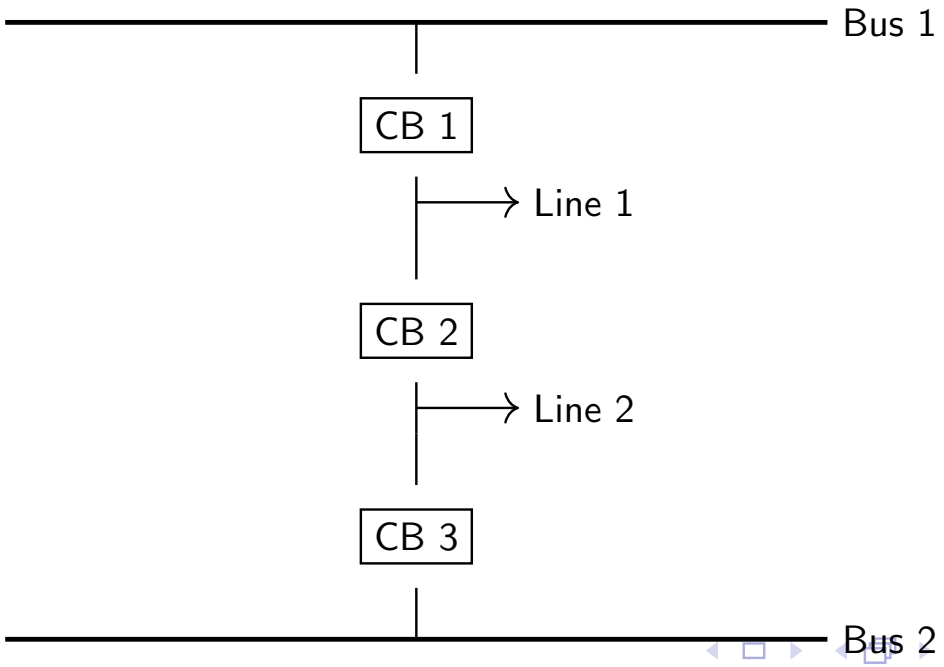


Double Bus Double Breaker: Pros & Cons

- Advantages:
- - Unmatched reliability and flexibility.
- - No interruption for bus or breaker faults/maintenance.
- - Simple protection relaying schemes.
- Disadvantages:
- - Extremely expensive (requires twice the number of circuit breakers).
- - Requires a massive amount of physical space in the switchyard.

One-and-a-Half Breaker System

- The industry standard for Extra High Voltage (EHV - 400kV and above).
- Two main buses. Three circuit breakers are used to protect two circuits.
- Therefore, there are 1.5 breakers per circuit (3 breakers / 2 circuits).
- The three breakers are connected in series between Bus 1 and Bus 2, forming a 'diameter'.



Operation of One-and-a-Half Breaker

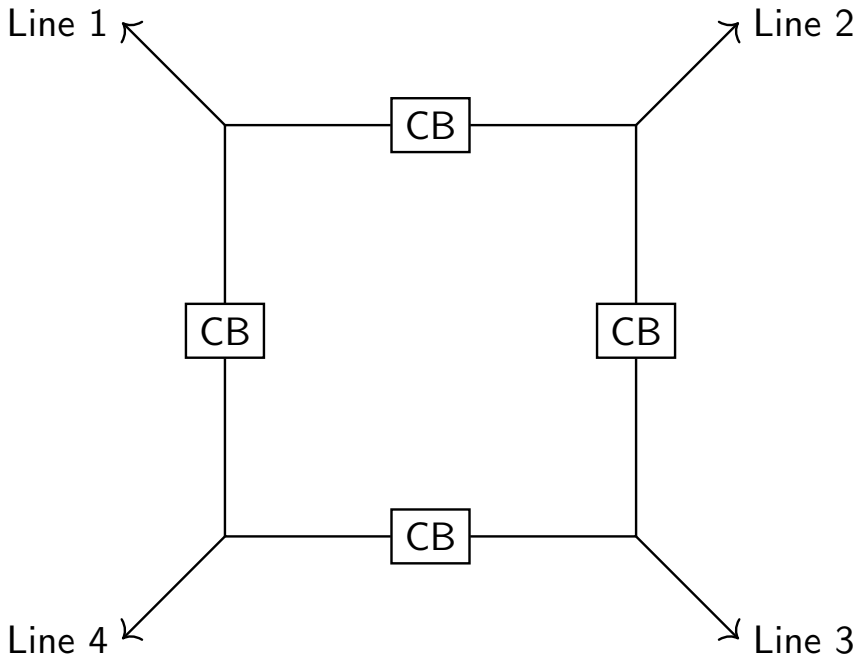
- Normal Operation: All three breakers are closed. Both buses are energized.
- Breaker Maintenance: Any single breaker can be opened for maintenance without interrupting either circuit.
- Bus Fault: If Bus 1 faults, the breakers connected to it trip. Power continues to flow to both circuits via Bus 2 and the middle 'tie' breaker.

Why 1.5 Breaker is Preferred

- Cost-effective high reliability: Saves one breaker per two circuits compared to Double Breaker.
- Highly resilient: A fault on a bus AND a simultaneous breaker failure still might not drop the load.
- Easy addition of new circuits: Just add another 'diameter'.
- Drawback: Complex protection relaying, especially for the middle 'tie' breaker which must protect either Line 1 or Line 2 depending on the fault location.

Ring Bus (Mesh) System

- Breakers are arranged in a closed ring or loop.
- Circuits tap off between the breakers.
- Number of breakers equals the number of circuits (1 breaker per circuit).
- Power can flow in both directions around the ring.



Ring Bus: Advantages and Limitations

- Advantages:
- - Low cost (one breaker per circuit).
- - Any breaker can be maintained without losing a circuit.
- - High reliability against bus faults (there is no 'main bus', just the interconnections).
- Limitations:
- - If one breaker is out for maintenance, the ring is 'open'. A subsequent fault splits the station in two.
- - Difficult to expand beyond 6 circuits without compromising reliability.

Comparison of Busbar Schemes

Scheme	Breakers/Circuit	Reliability	Cost	Maintenance Flexibility
Single Bus	1	Low	Lowest	Poor
Main & Transfer	1 + 1 (Coupler)	Moderate	Low	Good (Breaker only)
Ring Bus	1	High	Moderate	Good
1.5 Breaker	1.5	Very High	High	Excellent
Double Breaker	2	Highest	Highest	Excellent

Selection Guidelines by Voltage

- 11kV / 33kV: Single Busbar or Single Busbar with Sectionalization. Cost is the primary driver.
- 66kV / 132kV: Main and Transfer Bus, or Double Bus Single Breaker. Balance of cost and maintenance needs.
- 220kV / 400kV / 765kV: One-and-a-Half Breaker or Ring Bus. Reliability is paramount to prevent grid collapse.

Summary

- Advanced busbar systems use multiple breakers and buses to provide redundancy.
- Double Bus Double Breaker is the most reliable but most expensive.
- One-and-a-Half Breaker is the preferred standard for extra-high voltage transmission.
- Ring Bus offers great reliability for a small number of circuits at lower cost.
- Selection depends entirely on the criticality of the load and the voltage level.