Substation Engineering

Routine Substation Operations (Part 2 of 3)

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Routine Substation Operations (Part 2 of 3)

- Course: Substation Engineering (DI04009011)
- Unit 5: Auxiliary Systems and Routine Operations
- Lecture 24: Bus Transfer and Complex Switching

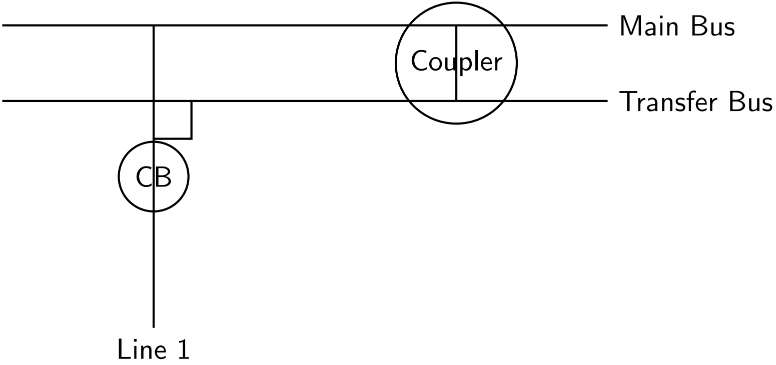
Agenda

- The Concept of Bus Transfer
- Main and Transfer Bus Switching Sequence
- Double Bus Single Breaker Transfer
- Breaker-and-a-Half Scheme Operations
- Transformer Energization (Inrush Current)
- Capacitor Bank and Reactor Switching

The Concept of Bus Transfer

- Objective: To take a busbar or a circuit breaker out for maintenance without interrupting power to the connected lines
- Requires 'paralleling' the two buses temporarily before opening the old path
- Make-before-break operation: The new path is closed before the old path is opened
- Requires careful synchronization and checking that phase angles are identical
- Protection relay settings often need to be modified or transferred during the process

Main and Transfer Bus Scheme (Review)



- Normal Operation: Line connects to Main Bus via its dedicated Line Breaker
- Transfer Bus is normally de-energized
- Bus Coupler Breaker (Transfer Breaker) is open
- Goal: Take the Line Breaker out for maintenance while keeping the line energized via the Transfer Bus

Switching Sequence: Main to Transfer Bus

- Step 1: Close Bus Coupler Isolators (Main and Transfer side)
- Step 2: Close Bus Coupler Breaker (energizes the Transfer Bus)
- Step 3: Verify Transfer Bus voltage is healthy
- Step 4: Close the Transfer Isolator for the specific line (parallels the breakers)
- Step 5: Open the Line's dedicated Circuit Breaker
- Step 6: Open the Line's Main Bus Isolator (isolates the breaker)

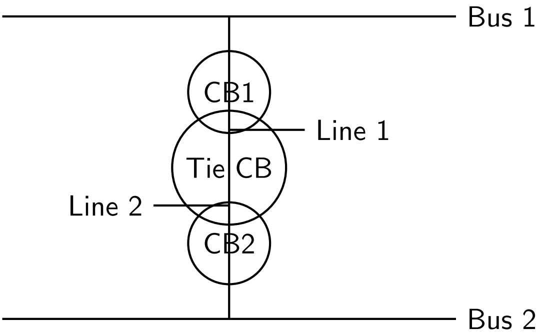
Protection Transfer During Bus Transfer

- When transferring a line to the Bus Coupler, the Line Breaker's protection relays must be switched over
- The Bus Coupler must now trip if a fault occurs on the line
- Trip circuits are physically switched using a 'Transfer Switch' on the control panel
- Current Transformer (CT) secondary circuits may also be switched to the Bus Coupler relays
- Failure to transfer protection leaves the line unprotected or causes bus bar trips

Double Bus Single Breaker Transfer

- Objective: Move a line from Bus 1 to Bus 2 without interruption
- Step 1: Close Bus Coupler Isolators and Breaker (parallels Bus 1 and Bus 2)
- Step 2: Close the Bus 2 Isolator for the target line (Make)
- Step 3: Open the Bus 1 Isolator for the target line (Break)
- Step 4: Open Bus Coupler Breaker (if required to split buses again)

Breaker-and-a-Half Scheme Operations



- Three breakers in series between two main buses, serving two circuits
- Normal operation: All three breakers are CLOSED. Both buses energized
- Taking a bus out: Simply open all breakers adjacent to that bus. No load is lost
- Taking a breaker out: Open the specific breaker and its

Switching Complexities Comparison

Bus Scheme	Operational Flexibility	Switching Complexity	Maintenance Outage Impact
Single Bus	Low	Simple	High (drops load)
Main & Transfer	Moderate	High (complex sequences)	Low (transfer via coupler)
Double Bus	High	High (bus paralleling)	Low
Breaker-and-a-Half	Very High	Low (just open breaker)	None (redundant paths)

Transformer Energization: Inrush Currents

- Energizing a power transformer draws a massive transient 'magnetizing inrush current'
- Can be up to 10-15 times the full load current, lasting several cycles
- Caused by the core magnetic flux saturating depending on the point-on-wave of closing
- Operations impact: Inrush can cause voltage dips on the busbar
- Differential relays must be configured with harmonic restraint to avoid false tripping during energization

Transformer Switching Sequences

- Always energize from the High Voltage (HV) side if possible (lower inrush current due to higher impedance)
- Energizing: Close HV breaker -¿ Wait for inrush to subside -¿ Close LV breaker to connect load
- De-energizing: Open LV breaker (drop load) -¿ Open HV breaker (drop magnetizing current)
- Tap changers (OLTC) should be set to proper tap before paralleling transformers
- Cooling fans/pumps must be confirmed operational

Capacitor Bank Switching

- Used for voltage support and power factor correction
- Switching capacitors causes severe high-frequency voltage and current transients
- Energizing creates high inrush currents; de-energizing risks restrikes in the breaker
- Point-on-Wave (Synchronous) Switching relays are often used to close contacts exactly at voltage zero
- Operators must wait for internal discharge resistors to drain voltage before re-closing (typically 5 minutes)

Reactor Switching Operations

- Shunt reactors absorb reactive power to lower voltage on long transmission lines
- Switching highly inductive loads is difficult for circuit breakers (current chopping)
- Current chopping forces current to zero prematurely, causing massive overvoltage spikes (L*di/dt)
- Breakers for reactors are often fitted with surge arresters or specialized contacts
- Synchronous switching is also used here (opening at current zero)

Summary

- Bus transfers require paralleling buses to allow make-before-break switching
- Protection schemes must be transferred along with the primary current paths
- Breaker-and-a-half schemes simplify switching by eliminating bus transfer sequences
- Transformer energization requires managing massive magnetizing inrush currents
- Switching reactive equipment (caps and reactors) creates severe electrical transients

Preview of Next Lecture

- Substation Grounding Procedures
- Temporary Protective Grounds
- Permit to Work (PTW) Systems
- Step and Touch Potential Risks during operations
- Logbooks, Shift Handovers, and Record Keeping