Substation Engineering

Routine Substation Operations (Part 1 of 3)

Milav Dabgar

Routine Substation Operations (Part 1 of 3)

- Course: Substation Engineering (DI04009011)
- Unit 5: Auxiliary Systems and Routine Operations
- Lecture 23: Switching Principles and Isolation

Agenda

- Introduction to Substation Operations
- Circuit Breakers vs. Isolators
- General Rules for Safe Switching Sequences
- Interlocking Schemes (Electrical and Mechanical)
- Line Energization and De-energization Procedures
- Isolation and Tagging (Lockout/Tagout)

Introduction to Routine Operations

- Substation operations involve changing the topology of the electrical network
- Purpose: Taking equipment out for maintenance, transferring loads, or isolating faults
- Performed locally via control panels or remotely via SCADA
- Requires strict adherence to authorized switching programs
- Safety of personnel and equipment is the highest priority

Circuit Breakers vs. Isolators (Disconnect Switches)

Feature	Circuit Breaker (CB)	Isolator (Disconnect Switch)
Load Current Breaking	Yes, designed to interrupt full load	No, cannot break load current
Fault Current Breaking	Yes, interrupts short circuits	No, will cause massive arc if opened under fault
Arc Quenching Medium	SF6, Vacuum, Oil	Air (no dedicated quenching chamber)
Visual Isolation	Enclosed contacts (cannot see)	Visible break in the air
Operation Speed	Very fast (cycles)	Slow (motorized or manual)

Safe Switching Principles

- Always use the Circuit Breaker to interrupt or initiate current flow
- Isolators are operated only when the associated Circuit Breaker is OPEN
- Earth switches are closed only after the equipment is fully isolated and verified dead
- Verify the open/close status of devices visually and via panel indicators
- Never bypass safety interlocks without explicit high-level authorization

Line De-energization Procedure

- Step 1: Open the Line Circuit Breaker (interrupts load current)
- Step 2: Verify zero current and breaker open status
- Step 3: Open the Line Isolator (creates a visible gap to the line)
- Step 4: Open the Bus Isolator (creates a visible gap to the busbar)
- Step 5: Lock and tag isolators in the open position

Line Energization Procedure

- Energization is the exact reverse of de-energization
- Step 1: Verify all Earth Switches are OPEN and clearances are canceled
- Step 2: Close the Bus Isolator
- Step 3: Close the Line Isolator
- Step 4: Close the Circuit Breaker (initiates current flow)
- Step 5: Verify voltage and current on panel meters

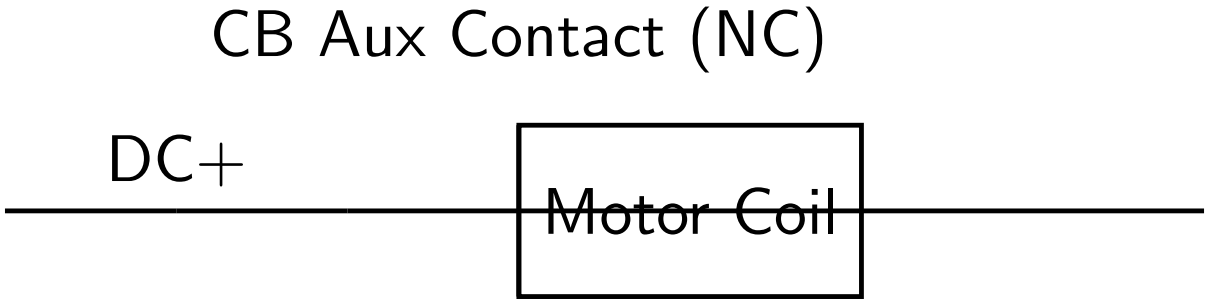
Substation Interlocking Schemes

- Interlocks prevent incorrect sequence of operations
- They enforce the rule: Isolator cannot move unless the Breaker is OPEN
- Earth switch cannot close unless the Isolator is OPEN
- Protects against human error, stress, and miscommunication
- Two main types: Mechanical and Electrical Interlocks

Electrical vs. Mechanical Interlocks

Feature	Electrical Interlocking	Mechanical / Key Interlocking (Castell Keys)
Mechanism	Auxiliary contacts in control circuits	Physical keys trapped in locks
Application	Motor-operated isolators, complex bus schemes	Manual isolators, earth switches, simple bays
Flexibility	High, easily integrated into SCADA	Low, physically rigid
Reliability	Dependent on DC control voltage	Highly reliable, failsafe, requires no power

Electrical Interlocking Scheme (Example)



- Control circuit for the Motor Operated Isolator (MOI)
- A Normally Closed (NC) auxiliary contact of the Circuit Breaker is wired in series with the Isolator's motor contactor
- If the CB is closed, the NC contact opens, breaking the circuit to the Isolator motor
- Result: Pressing the 'Open' or 'Close' button on the Isolator has no effect

Visual Verification of Contacts

- Never trust panel indicator lights alone (lamps can fail or stick)
- Operators must physically walk to the switchyard and visually confirm all 3 phases of an isolator are fully open
- Look for proper alignment of the male and female contacts when closed
- Binoculars are often used to inspect elevated isolators
- Confirming the physical 'air gap' is mandatory before issuing work permits

Isolation and Tagging (LOTO)

- Lockout / Tagout (LOTO) secures equipment for maintenance
- Lockout: Applying physical padlocks to isolator operating handles or control switches
- Tagout: Attaching prominent 'DO NOT OPERATE' warning tags with the operator's details
- Control circuit fuses are also pulled to prevent remote SCADA operation
- Ensures no one can accidentally re-energize the circuit while workers are present

Communication Protocols During Switching

- Use of three-way communication to prevent misunderstandings
- 1. Dispatcher gives command (e.g., 'Open Breaker 52-1')
- 2. Operator repeats command back ('Repeat: Open Breaker 52-1')
- 3. Dispatcher confirms ('That is correct, execute')
- Standardized nomenclature must be used (no slang or abbreviations)
- All commands are recorded in voice logs and written switching programs

Summary

- Breakers break load current; Isolators provide visual isolation and cannot break load
- Always operate Isolators under no-load conditions (Breaker open)
- Interlocks (electrical and mechanical) enforce proper switching sequences
- Visual verification of physical switchyard contacts is mandatory
- LOTO and strict communication protocols protect personnel during maintenance

Preview of Next Lecture

- Bus Transfer Operations
- Switching in Main and Transfer Bus schemes
- Double Bus Double Breaker operations
- Breaker-and-a-Half scheme switching complexities
- Transformer and Capacitor Bank switching