The X, Y, and Z of Circuit Breaker Control

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Agenda

- Importance of Breaker Control
- The IEEE C37.11 Standard
- Breaker control circuit
  - 12 step program for breaker closing
  - Trip coil monitoring
  - Seal-in
  - Anti-pump
- Demonstrations
The importance of breaker control

- **Mechanical forces**
  - Acceleration-Travel-Deceleration
  - Very fast from one closed to open, or open to closed (e.g. 3 cycles = 0.050 seconds)

- **Electrical forces**
  - Magnetic forces from fault currents (e.g. 40,000 Amps)
The importance of breaker control
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IEEE C37.11

IEEE Standard Requirements for Electrical Control for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

Contains 5 Sections

1. Overview
2. References
3. Functional Requirements
4. Devices and Auxiliaries
5. Wiring Requirements
IEEE C37.11
Section 5:
Wiring Requirements
### Table 1 — Circuit breaker intended for use in metal-clad switchgear

<table>
<thead>
<tr>
<th>Closing power</th>
<th>Closing control</th>
<th>Tripping control</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>dc</td>
<td>dc</td>
<td>dc</td>
<td>1</td>
</tr>
<tr>
<td>ac</td>
<td>ac</td>
<td>dc</td>
<td>2</td>
</tr>
<tr>
<td>ac</td>
<td>ac</td>
<td>Capacitor trip</td>
<td>3</td>
</tr>
<tr>
<td>ac</td>
<td>dc</td>
<td>dc</td>
<td>4</td>
</tr>
</tbody>
</table>

### Table 2 — Circuit breaker not intended for use in metal-clad switchgear

<table>
<thead>
<tr>
<th>Closing power</th>
<th>Closing control</th>
<th>Tripping control</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>dc</td>
<td>dc</td>
<td>dc</td>
<td>5</td>
</tr>
<tr>
<td>ac</td>
<td>ac/dc</td>
<td>dc</td>
<td>6</td>
</tr>
<tr>
<td>ac</td>
<td>ac</td>
<td>Capacitor trip</td>
<td>7</td>
</tr>
<tr>
<td>Pneumatic/hydraulic</td>
<td>dc</td>
<td>dc</td>
<td>8</td>
</tr>
</tbody>
</table>
Section 5: Wiring Requirements

Figure 6 — Circuit breaker NOT intended for use in metal-clad switchgear, where the closing power is ac; the closing control is ac or dc; the tripping control is dc.
Section 5: Wiring Requirements
Section 5: Wiring Requirements

![Diagram of wiring requirements]

**Figure 6**—Circuit breaker NOT intended for use in metal-clad switchgear, where the closing power is ac; the closing control is ac or dc; the tripping control is dc.
Section 5: Wiring Requirements
Circuit Breaker Controls
The 12 Step Program for Successful Breaker Closing
1. “Normal” state

- Breaker is open
- Mechanism is not charged
- Control power is not applied
2. Apply Closing Power

- Motor (88) runs to charge mechanism
3. Mechanism charged

- All 63 contacts change state
- Motor stops running
4. Apply Control Power

- Breaker is still open
- Green light is on
5. Close Command

- Energizes 52X relay
6. 52X Relay Operates

- All 52X contacts change state
- Energizes 52CC breaker closing coil
- 52CC releases energy to close the breaker
7. Breaker Closing

- Breaker begins to close
- All 52b contacts open
8. Breaker Closed

- All 52a contacts close
- Energizes 52Y relay
- Red light is on (trip coil monitoring)
Sidebar: Trip Coil Monitoring

- Q: Why does this circuit not trip the breaker? It is a complete circuit.

- A: Circuit is a voltage divider (two impedances in series), and the Red Light is a much larger impedance than the Trip Coil.

- Example: 48 Vdc control circuit

  Red Lamp = 1200 ohms; Trip Coil = 3 ohms

  Voltage across the Red Light = $48 \times 1200 / (1200+3) = 47.88$ V
  Voltage across the Trip Coil = $48 \times 3 / (1200+3) = 0.12$ V

  Power absorbed by the Red Light = $47.88^2 / 1200 = 1.9$ Watts
  Power absorbed by the Trip Coil = $0.12^2 / 3 = 0.005$ Watts

  Current in the circuit = $48 / (1200+3) = 0.040$ A

  Current through the trip coil during a trip = $48 / 3 = 16$ A
Q: Why does the trip coil always have a 52a contact in series with it?

A: 3 Reasons:

1. Block energizing the coil when the breaker is already open.
2. Trip coil passes a lot of current (e.g. 16 Amps in the previous example; often more). 52a is a heavy-duty contact that is rated to interrupt that current so that the tripping devices (relays) do not have to.
3. Trip coil is not rated for continuous current. It needs to be de-energized as soon as possible after it has done its job to trip the breaker.

Q: Why use a coil that isn’t rated for continuous use?

A: Speed.

And... Because we are intentionally over-dutying the trip coil, trip coil monitoring is critically important.
9. 52Y Relay Operates

- All 52Y contacts change state
- 52X relay drops out
10. 52X Relay Resets

- All 52X contacts change state back to normal
- 52CC drops out
11. Close Command is Released

- *52Y relay drops out*
12. 52Y Relay Resets

- All 52Y contacts change state back to normal
- Closing cycle complete
Breaker Tripping
Breaker Trip
Breaker Trip

- *Trip command*
Breaker Trip

- Trip command
- Energizes 52TC breaker trip coil
- Breaker begins to open
Breaker Trip

- *Trip command*
- *Energizes 52TC breaker trip coil*
- *Breaker begins to open*
- *52a contacts open*
Breaker Trip

- Trip command
- Energizes 52TC breaker trip coil
- Breaker begins to open
- 52a contacts open
- Breaker fully open
- 52b contacts close
Breaker Trip

- Trip command
- Energizes 52TC breaker trip coil
- Breaker begins to open
- 52a contacts open
- Breaker fully open
- 52b contacts close
- Trip command is released
IEEE C37.11
Section 3:
Functional Requirements
C37.11 Part 3: Functional Requirements

3a) Seal-in for close
3b) Anti-pump
3c) Reset after an incomplete close
3d) No close operation if already closed
3e) Block close for low stored energy
3f) Low gas block trip and close
3g) Low gas alarm
3h) Block close if tripped free
3i) Pressure nuisance alarms
3j) Pole disagreement tripping
IEEE C37.11
Section 3e
3e) Block close for low stored energy

- Breaker is open
3e) Block close for low stored energy

- Breaker is open
- Low stored energy
- 63 contact in the close control circuit accomplishes the 3e) requirements
IEEE C37.11
Section 3d
3d) No close if already closed

- Breaker is closed
- 52b contact in the close control circuit accomplishes the 3d) requirements
- Just like the 52a prevents re-energizing the trip coil if the breaker is already open
- Demonstration
IEEE C37.11
Section 3a
3a) Seal-in for close

- Breaker is open
- Step 5. 52X relay is energized
- Step 6. 52X relay operates
- What happens if the close command drops out before the breaker completes its close cycle?

  - Doesn’t matter. 52X is sealed-in.

- Demonstration
IEEE C37.11
Section 3c
3c) Reset after an incomplete close

- 52X seal-in lasts forever
- Must fully reset if control power is cycled
3c) Reset after an incomplete close

- 52X seal-in lasts forever
- Must fully reset if control power is cycled
- 52X drops out and contacts return to normal
3c) Reset after an incomplete close

- **52X seal-in lasts forever**
- **Must fully reset if control power is cycled**
- **52X drops out and contacts return to normal**
- **Restoring control power does not cause 52X to pick up and does not result in the breaker closing; all devices remain reset**

- **Demonstration**
IEEE C37.11
Section 3b
3b) Anti-pumping

- Breaker is open
- Step 7. Closing coil operates
3b) Anti-pumping

- 52b contact opens
- Breaker closes
- 52a contact closes
3b) Anti-pumping

- 52b contact opens
- Breaker closes
- 52a contact closes
- 52Y relay energizes
- 52Y contacts change state
3b) Anti-pumping

- 52b contact opens
- Breaker closes
- 52a contact closes
- 52Y relay energizes
- 52Y contacts change state
- 52X relay drops out
- 52CC drops out

- But what if closing in to a fault?
3b) Anti-pumping

- Breaker closes
  ... Into a fault!
3b) Anti-pumping

- **Breaker closes**
  ... Into a fault!
- **Same 52Y energize, 52X drop out, 52CC drop out**
3b) Anti-pumping

- *Breaker closes*  
  ... *Into a fault!*

- *Same 52Y energize, 52X drop out, 52CC drop out*

- *Relay trip to the breaker*
3b) Anti-pumping

- Breaker closes
  ... Into a fault!

- Same 52Y energize, 52X drop out, 52CC drop out

- Relay trip to the breaker

- Breaker opens

- Even though there is still a close command, the breaker will not close.

- Demonstration
3b) Anti-pumping
3b) Anti-pumping
Summary
Summary

- Breaker terminal block numbers
  - Specified in IEEE C37.11
  - Can vary depending on type of breaker and AC/DC

- Trip Coil Monitoring (TCM)
  - Required in the standard for most breaker types
  - Good practice for other devices as well (86 lockout relays), especially when the coil is not rated for continuous duty

- IEEE C37.11
  - Primarily applies to circuit breaker manufacturers
  - But... it is important for engineers and techs and wiremen to understand X/Y schemes
    - Maintenance, testing, and troubleshooting operations
Summary

- **X/Y Schemes**
  - Protect the breaker and are required by IEEE C37.11
  - Schematics can be confusing; work through one action/reaction one step at a time.
  - If you can sequence an X/Y scheme, you can do any schematic!

- **52X relay provides Seal-In for closing**
  - Remember this if troubleshooting a stuck breaker
  - Not all breaker types need a 52X relay

- **52Y relay provides Anti-Pump protection**
  - The breaker’s 52Y relay can be fooled by chattering closing relays (25, 27/59, 79) or worn contacts on closing devices (relays, 01, SCADA)
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