Get in Step with Synchronization
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Our Synchronization Discussion

- What are some ways to synchronize my sources?
- What are common sync-check settings?
- How can I safeguard automatic closing?
- What can modern relays do for me?
War of the Currents

- Alternating current vs. direct current
- How to connect two ac systems?

<table>
<thead>
<tr>
<th>AC</th>
<th>Poly-phase AC</th>
<th>DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>George Westinghouse</td>
<td>Nicola Tesla</td>
<td>Thomas Edison</td>
</tr>
</tbody>
</table>
Connecting Two AC Systems

- Match: phase sequence

Get This Right, First!
Connecting Two AC Systems

- Match: voltage amplitude

\[ \Delta v \]
Connecting Two AC Systems

- Match: frequency

\[ \omega' > \omega \]
- Match: phase angle
Add Live/Dead Voltage-Monitor

\[ \Delta V \text{– Voltage Difference} \]

\[ \theta \text{– Phase (Slip) Angle} \]

\[ V_B \text{ (bus)} \]

\[ V_L \text{ (line)} \]

Dead (Line/Bus)

Live (Line/Bus)
Instantaneous Slip Effect

$\Delta f$–Slip Frequency (Hz)

$\Delta V$–Voltage Difference

$\theta$–Phase (Slip) Angle

$\delta f$–Slip Frequency

$\delta V$–Voltage Difference

VL (line)

VB (bus)

Dead (Line/Bus)

Live (Line/Bus)
Auto-Sync 25A Window

- $\Delta V$ – Voltage Difference
- $25A$ Angle
- $\theta$ – Phase (Slip) Angle
- $V_B$ (bus)
- $V_L$ (line)
- Dead (Line/Bus)
- Live (Line/Bus)
Ways to Synchronize

- Manual
  - Operator close
  - Synchroscope, lamps, meters

- Assisted Manual
  - Operator commands close
  - Sync-check relay supervision

- Automatic
  - Synchronizer matches V and F, and closes
  - Sync-check relay supervision
Tools for Synchronizing
Synchroscope Indicates “Midnight”
Manual Synchronization

- Two bright, one dark lamp
Assisted-Manual Synchronization

Operator
Manual
Switch

Sync-Check
25 Allowed
Close

0°

Phasor
Rotation
Sync-Check Parameters

- Typical settings regions
- Modify for particular requirements
  - Rotating machines
  - Bus to bus

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical Value</th>
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<tbody>
<tr>
<td>Voltage Difference</td>
<td>10–15% V</td>
</tr>
<tr>
<td>Phase (Slip) Angle</td>
<td>0°–30°</td>
</tr>
<tr>
<td>Slip Frequency</td>
<td>0.05–0.10 Hz</td>
</tr>
</tbody>
</table>
- Senses bus and gen pts
- Raises and lowers, voltage and frequency
- Issues close command when synced
Anticipatory: Close Before 0°

- Issue close command at advance angle—“anticipate midnight”

- \[ AA = 360° \cdot (TCB + TR) \cdot FS \]
  - AA advance angle
  - TCB circuit-breaker close time
  - TR output relay travel (6–8 ms)
  - FS is the slip frequency
Angle and Time and Slip
- 25A - Autosynchronizer
- 25 - Sync Check
- 43 - Switch
Manual Supervised Close

DC BUS +

Interlocks

Enable 43M

Manual Close

Enable 43A

25A Close

25 Sync Check

DC BUS –

- 25A - Autosynchronizer
- 25   - Sync Check
- 43   - Switch
Automatic Supervised Close

- 25A - Autosynchronizer
- 25  - Sync Check
- 43  - Switch
- Sync across wye/delta transformer?
  - Old: phase-shift aux transformers
  - New: modern relays match all pt connections
- Connect pt phase to phase
  - Phase-to-neutral pts: unreliable voltage output
  - Phase-to-phase pts: no neutral offset
Conclusions

- Understand your sync-check and synchronization methods
- There are many ways to synchronize
- Voltage, acceptance angle, and slip frequency differ for rotating machines and line-to-bus applications
Conclusions, cont.

- Automatic synchronizer 25A adjusts voltage and frequency
- Anticipatory synchronizer adjusts for circuit-breaker closing time
- Supervise automatic and manual close with sync check 25
- Modern sync check compensates for pt connections and phase angle
Thank you for your attention.