SDG&E Relay Standards – Updating Tertiary Bus and Reactor Protection

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Introduction

• Overview of shunt reactor design
• Shunt reactor protection and design
• Tertiary-connected, air-core shunt reactor
• Overview of SDG&E system and standards
  ▪ Existing standards
  ▪ Future standards
  ▪ Protection scheme and set points
Overview of Shunt Reactor

(a) Bus-Connected Shunt Reactor

(b) Line-Connected Shunt Reactors

(c) Transformer Tertiary-Connected Shunt Reactor

- Above 52 kV usually directly connected at bus
- Typical reactor size 30–300 MVAR
- Single phase 125–375 MVAR

Overview of Shunt Reactor

- Three-legged gapped iron core
- Five-legged gapped iron core
- Shell-type gapped iron core
- Coreless (air core)
• Instantaneous overcurrent (50)
• Time-delayed overcurrent (51)
• Negative-sequence (46)
• Ground overvoltage (59N)
• Special schemes: turn-to-turn (T-T) faults
Tertiary-Connected, Dry-Type Reactor Protection

- Phase differential
  - Transformer differential (87T) when shunt reactor included in power transformer
  - Separate reactor phase differential protection
- Breaker failure (50BF)

Tertiary Bus Ground Voltage

Transformer Tertiary

Tertiary Bus

Grounding Transformer

Grounding Resistor

Ground Overvoltage Protection

Shunt Reactor
Tertiary Reactor – Normal and Fault Scenarios

SDG&E Shunt Reactor Upgrade 1 – 2004
### Winding / Connection

<table>
<thead>
<tr>
<th>Device</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wdg. S</td>
<td>12 kV bus, 3-phase CT, delta</td>
</tr>
<tr>
<td>Wdg. T</td>
<td>Reactor 1, 3-phase CT, wye</td>
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<tr>
<td>Wdg. U</td>
<td>Reactor 2, 3-phase CT, wye</td>
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<tr>
<td>Wdg. W</td>
<td>Reactor 3, 3-phase CT, wye</td>
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<tr>
<td>Wdg. X</td>
<td>Reactor 4, 3-phase CT, wye</td>
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<tr>
<td>VAV</td>
<td>12 kV ground detection, 3-phase PT = 3V0</td>
</tr>
<tr>
<td>VBV</td>
<td>Reactor 1, 1-phase PT = V0</td>
</tr>
<tr>
<td>VCV</td>
<td>Reactor 2, 1-phase PT = V0</td>
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<td>VAZ</td>
<td>Reactor 3, 1-phase PT = V0</td>
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<tr>
<td>VBZ</td>
<td>Reactor 4, 1-phase PT = V0</td>
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<tr>
<td>VCZ</td>
<td>VAB 12 kV bus, Voltage reference</td>
</tr>
</tbody>
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### Tertiary Fault – Neutral Side of Reactor

- 3V0 Tertiary Bus
- OV SP 1
- GND ALM
- Bus Neg
- SEQ IOC
- 120 cyc
- 0 cyc
- Bus FLT Trip
- Trip XFMR and LO
- TERT Bus Fault ALM
Front-Panel Design Details

F1 / F2 and Protection Discussion

- **F1 fault**
  - 3P – 87R / 50P
  - PP – 87R / 50P

- **F2 fault**
  - 3P – 87R
  - PP – 87R / 50Q / 51Q

F1 / F2 faults require opening high-side breakers
Protection Element Guidelines

- Differential (87P)
- Phase overcurrent (50P / 51P) on bank tertiary current transformer (CT) winding
- Negative-sequence (50Q / 51Q) on bank tertiary CT winding
- T-T (50 / 51Q) on reactor breaker CTs
- V0 and 3V0 (59 ground detection, custom logic)

Protection Element Guidelines – DIFF

Differential (87R)

\[ O87P = 0.2 \times \text{INOM} = 0.2 \times 8660 \text{ A} = 1732 \text{ A} \]

- Adaptive slope
- Phase-to-phase fault = 1875 A
- SLP1 = 15%
- SLP2 = 50%
Protection Element Guidelines – Overcurrent

50P / 51P element
- $50P = 1.1 \times 1.25 \times \text{INOM}$
- \text{INOM} = 4 \times 45 \text{ MVAR} = 8660 \text{ A}
- $50P = 1.1 \times 1.25 \times 8660 \text{ A} = 11,900 \text{ A}$
- 51P OFF

Protection Element Guidelines – Overcurrent

50Q / 51Q element
- $50Q = 0.4 \times 3264 \text{ A} = 1300 \text{ A}$
- $51Q = 0.2 \times 3264 \text{ A} = 650 \text{ A}$
- IEEE Inverse and time dial = 0.5
**Reactor Breaker Turn-to-Turn Fault**
**Negative-Sequence Overcurrent (46)**

- Breaker on neutral
- Opening breaker clears T-T fault
- Inductance varies with turn short
  - \((0.95)^2 \cdot X_L = 0.9 \cdot X_L\)
  - \((0.90)^2 \cdot X_L = 0.8 \cdot X_L\)
- 150 A pickup provides 2.6% T-T, 2 seconds

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**Conclusion**

- Dry-type tertiary bus and reactor protection standards
- SDG&E protection design using modern relays
- Improved redundancy and simplified design
- Negative-sequence overcurrent with ground detection
- Protection element selection and settings
- Design and documentation
Questions?