Application Considerations for Protecting Transformers With Dual Breaker Terminals

Shahab Uddin and Abu Bapary
*American Electric Power*

Michael Thompson, Ryan McDaniel, and Kunal Salunkhe
*Schweitzer Engineering Laboratories, Inc.*
Key Concepts of Paper

• Transformers in dual breaker buses
  ▪ Conflicting requirements
  ▪ Tradeoffs using an overall differential zone
• Scheme design choices

• Setting concepts
  ▪ CTR selection
  ▪ Key relay settings
• Solutions for legacy installations
Subzones of Dual Breaker Transformer Zone

**87B Zone**
- High through fault
- High speed
- Low sensitivity

**87T Zone**
- High sensitivity
- Relatively high speed
- Low through fault

Diagram showing the tripping zone.
Conflicting CTR Requirements

- High enough to not limit loadability
  Bus >> Transformer
- Low enough for sensitivity
  Transformer << Bus
- High enough to not saturate during through fault
  Bus >> Transformer
- Asymmetrical current drives saturation
- Core area drives volts / turn
- Square of turns drives performance
  - Fewer turns reduces voltage available
  - Fewer turns increases voltage required
Effect of MVA Setting on 87T
Three Options for System Design

- Two-relay scheme
- Three-relay scheme
- Four-relay scheme
• Benefits
  ▪ Low cost – only two relays
  ▪ Moderate setting complexity
  ▪ Least panel space and wiring

• Drawbacks
  ▪ Tradeoff
    – Sensitivity of 87T zone
    – Loadability and security of 87B zone
  ▪ Reduced speed of 87B zone
  ▪ Ambiguous fault location
Three-Relay Scheme

• Benefits
  ▪ Balance cost and performance
  ▪ High sensitivity and security
  ▪ Moderate panel space and wiring
  ▪ Accurate fault location

• Drawbacks
  ▪ Most complex settings
  ▪ Loss of performance if 87T or 87B out of service
Four-Relay Scheme

- **Benefits**
  - Best performance
  - Least complex settings

- **Drawbacks**
  - Most relays
  - Most panel space
  - Most wiring
• Dual breaker terminals on both the high side and low side of the transformer
• Protection redundancy and hardware diversity
• Dual slope percent restraint for bus and transformer zones with unique settings for the manufacturers’ relays
AEP Standard

- High system reliability requires high-side bus restoration
- Guidance on through-path loadability and automatic restoration of a high-side bus
## Summary of Settings Considerations

<table>
<thead>
<tr>
<th>Application With Restraint Type</th>
<th>Slope 1</th>
<th>Slope 2</th>
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<tbody>
<tr>
<td>Transformer Differential</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
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<td>75</td>
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<td>Sum of magnitudes</td>
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<td>Sum of magnitudes</td>
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</tbody>
</table>
Legacy Applications
Compromises to Look For

• Inadequate security for through fault not limited by transformer impedance
• Inadequate bus loadability
• Inadequate transformer protection sensitivity
Possible Solutions
Partial Differential

- 87PD zone
- 50P and 87U considerations
  - Above inrush
  - Above BUS X fault
  - Above spurious differential current
  - Below internal bus fault
Possible Solutions

87B in Protection Logic

• Partial differential elements cannot be used

• Implement simple bus differential elements in protection logic
Summary

• Transformer and bus differential zones have inherently different performance and reliability requirements

• A single overall differential relay covering both zones can result in significant compromises

• Use of separate differential subzones is recommended

• A case study with detailed calculations helps solidify the concepts
Summary of Recommendations

• Evaluate if you have compromised protection
• Evaluate presented alternatives
• Use recommended guidelines to select CTRs
• Use base MVA for selecting tap factors
Questions