Negative-Sequence Overcurrent Considerations for Induction Motor Loads

Miles Dupuis
*Cleco Power LLC*

Nick Mahoney, Aadityaa Padmanabhan, and Krithika Bhuvaneshwaran
*Schweitzer Engineering Laboratories, Inc.*
Overview

• Sequence components
• Negative-sequence overcurrent protection
• Induction motor model and slip
• Real-world event analysis
• PSCAD simulations of event
• Settings recommendations
• Conclusion
Introduction to Sequence Components

Zero-Sequence
Single-Phase

Positive-Sequence
Balanced

Negative-Sequence
Balanced
# Negative-Sequence Overcurrent Protection

**Why Use This Element?**

<table>
<thead>
<tr>
<th>Element</th>
<th>Responds to Load?</th>
<th>Detects Phase-to-Phase Faults?</th>
<th>Detects Ground Faults?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase overcurrent</td>
<td>Yes</td>
<td>Yes</td>
<td>Limited</td>
</tr>
<tr>
<td>Ground overcurrent</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Negative-sequence overcurrent</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Negative-Sequence Overcurrent Protection

When to Use This Element?

- Feeder protection
- Transformer protection
- Motor protection
Induction Motor Model
• For positive-sequence current, 
  \[ s = 1 - \left( \frac{N_r}{N_s} \right) \]

• For negative-sequence current, 
  \[ s_2 = 1 - \left( \frac{N_r}{-N_s} \right) = 2 - s \]

• Typically, 
  \[ \left| \frac{Z_1}{Z_2} \right| \approx 6 \]
Real-World Event System
Real-World Event Analysis
Phase Relationship Before and During Fault
Sequence Network During Fault
Relay 2 Event Negative-Sequence Waveforms

Voltage

Current

Impedance

Time
PSCAD Simulations System Setup
Single-Line Diagram

- Single-Line Diagram
- 12.5 MVA
- 4.16 kV / 34.5 kV
- 6.0 Ω
- 0.99
- 1.0
- W, S, T
- IM
- AB ≥ G
- Timed Fault Logic
PSCAD Simulated Waveforms

Three-Phase Fault

Amperes (pu)

Time
PSCAD Simulated Waveforms
Phase-to-Ground Fault

Amperes (pu)

Time

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
PSCAD Simulated Waveforms
Phase-to-Phase Fault

Amperes (pu)

Time
Operation of Negative-Sequence Impedance Directional Element
PSCAD Simulated Waveforms
34.5 kV Bus Fault

Direction (Fwd = 1, Rev = –1)
PSCAD Simulated Waveforms
4.16 kV Bus Fault

-2.00
-1.50
-1.00
-0.50
0.00
0.50
1.00
1.50
2.00

Time

Direction (Fwd = 1, Rev = -1)
Relay 2 Waveforms
Directional Element Operation in Relay
Recommendations for Transformer Protection

- Inverse-time neutral overcurrent (51N)
- Restricted earth fault (REF)
- Inverse-time negative-sequence overcurrent (51Q)
  - Nondirectional
  - Directional
Conclusion

• Consider load type for 51Q element
• Nondirectional 51Q element when set sensitively leads to out-of-zone tripping
• Use directional supervision to set element sensitively