SEL-311L and SEL-411L
Line Differential Basics
SEL-311L Line Current Differential Protection and Automation System
SEL-311L Protection Elements

- Primary function is line current differential
- Also has distance, overcurrent, and other functions
Differentials for Different Applications

Line Differential Alpha Plane

Transformer Differential Restraint Slope

87LANG 2
Im \( \frac{I_R}{I_L} \)

1 ∠ 180°

Re \( \frac{I_R}{I_L} \)

87LR

Restraint Region

Trip Region

Operating Region

Slope 1 (SLP1)

Slope 2 (SLP2)

25%

60%

087P = 0.3

IRS1 = 3

IRT
SEL-311L Uses Alpha Plane for Each Element

\[
\begin{pmatrix}
\frac{I_R}{I_L} \\
\frac{1}{87LR}
\end{pmatrix}
\]

87LANG \frac{2}{2}

1 \angle 180°

Restraint Region

Trip Region
Alpha Plane Logic

* To allow for capacitive inrush, timer $\tau$ increases to 1 cycle and setting $87LPP$ doubles when:
  1. $3PO$ asserts and for 3 cycles after $3PO$ deasserts.
  2. For 1 cycle after any remote phase current exceeds local setting $50LP$ while the associated
87L Scheme Processing Logic

TRIP87 (direct to outputs)
Trip Logic

*CH_AL is CHKAL or CHYAL, whichever channel is active.
87LPP Element
Phase Setting Criteria

- Is factory-set at 6 A (1.2 pu in SEL-411L)
- Is set above line-charging current and load with shorted CTs at one end
- Is mainly used for three-phase faults

If CTR = 400 and 87LPP = 6, then trip point = 2,400 A primary
87L2P Element
Negative-Sequence Setting Criteria

• Is factory set at 10% of INOM or 0.5 A
• Is used to detect unbalanced faults (phase-to-phase, phase-to-ground, and phase-to-phase-to-ground)
• Is set above normal system and line-charging current unbalances
• Operates on 3I2 and is immune to line loading
• Is more sensitive than 87LPP element
87LGP Element
Zero-Sequence Setting Criteria

- Is factory set at 10% of INOM or 0.5 A
- Is used to detect ground faults (phase-to-phase-to-ground and phase-to-ground)
- Is set above normal system and line-charging current unbalances
- Operates on 3I0 and is immune to line loading
- Is more sensitive than 87LPP element
MET

Normal Load

Line CTs = 2,000 / 5, 87LPP = 6 A, and 87L2P = 1.0 A

<table>
<thead>
<tr>
<th>Local</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>3I0</th>
<th>3I2</th>
<th>I1</th>
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</thead>
<tbody>
<tr>
<td>I MAG (A Pri)</td>
<td>1196.657</td>
<td>1187.730</td>
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<td>-0.10</td>
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<td>120.00</td>
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<td>B</td>
<td>C</td>
<td>3I0</td>
<td>3I2</td>
<td>I1</td>
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<tr>
<td>I MAG (A Pri)</td>
<td>1192.154</td>
<td>1190.037</td>
<td>1184.124</td>
<td>10.453</td>
<td>12.028</td>
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<tr>
<td>I ANG (DEG)</td>
<td>179.70</td>
<td>59.90</td>
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<td>Vector Sum</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>3I0</td>
<td>3I2</td>
<td>I1</td>
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<tr>
<td>I MAG (A Pri)</td>
<td>6.136</td>
<td>3.102</td>
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<td>I ANG (DEG)</td>
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<td>17.90</td>
<td>5.00</td>
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<td>78.60</td>
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<tr>
<td>Alpha Plane</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>ZERO-SEQ</td>
<td>NEG-SEQ</td>
<td>POS-SEQ</td>
</tr>
<tr>
<td>RADIUS</td>
<td>0.990</td>
<td>1.000</td>
<td>1.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.990</td>
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<tr>
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</table>
What has changed? Do you think it will trip?

<table>
<thead>
<tr>
<th>Local</th>
<th>A</th>
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<th>C</th>
<th>310</th>
<th>312</th>
<th>I1</th>
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<tbody>
<tr>
<td>I MAG (A Pri)</td>
<td>1196.030</td>
<td>1186.419</td>
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<td>312</td>
<td>I1</td>
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<td>I MAG (A Pri)</td>
<td>1194.860</td>
<td>1189.160</td>
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<td>15.521</td>
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<td>C</td>
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<td>312</td>
<td>I1</td>
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<td>I MAG (A Pri)</td>
<td>2390.875</td>
<td>2375.571</td>
<td>2365.408</td>
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<td>B</td>
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<td>RADIUS</td>
<td>0.990</td>
<td>1.000</td>
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<td>0.000</td>
<td>0.000</td>
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<td>0.00</td>
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<td>0.40</td>
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MET

What has changed? Do you think it will trip?

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<tr>
<th>Local</th>
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<th>3I2</th>
<th>1I1</th>
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<tbody>
<tr>
<td>I MAG (A Pri)</td>
<td>997.723</td>
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<td>-178.20</td>
<td>-179.30</td>
<td>0.00</td>
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<td>Channel X</td>
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<td>C</td>
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<td>3I2</td>
<td>1I1</td>
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<td>I MAG (A Pri)</td>
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<td>-179.50</td>
<td>179.70</td>
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<td>Vector Sum</td>
<td>A</td>
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<td>C</td>
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<td>3I2</td>
<td>1I1</td>
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<td>C</td>
<td>ZERO-SEQ</td>
<td>NEG-SEQ</td>
<td>POS-SEQ</td>
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<td>RADIUS</td>
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<td>0.990</td>
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<td>179.40</td>
<td>179.90</td>
<td>3.30</td>
<td>0.10</td>
<td>179.70</td>
</tr>
</tbody>
</table>
COM X and COM X L

=>com x

SEL-311L  
EXAMPLE: BUS B, BREAKER 3

FID=SEL-311L-1-R214-V0-Z011005-D20100616  
CID=CA02

Summary for 87L Channel X

Channel Status Alarms
   ROKX = 1  DBADX = 0  RBADX = 0  AVAX = 0

For 02/23/2017 18:34:31.418 to 02/23/2017 19:14:27.509

COMMUNICATION LOG SUMMARY  
# of Error records  30  
Data Error          21  
Dropout             9  
Test Mode Entered   0  

=>com x 1

COMMUNICATION STATISTICS  
Last error  Data Error  
Longest failure  60.563 sec.  
Lost Packets, prev. 24 hours  49659  
One Way Delay (Ping-Pong)  0.6 msec.
SEL-411L Advanced Line Differential Protection, Automation, and Control System
SEL-411L Communications Ports

- **General**
  - Serial

- **Serial**
  - Fiber or Serial Differential

- **Ethernet**
  - Differential (later and trial applications)

- **Ethernet**
  - GOOSE, SCADA, Other

- **IRIG-B**
  - Time
SEL-411L Has Two CT Inputs
Example Line
Generalized Alpha Plane

- Four terminal lines – handle any number of currents
- Differential restraints – in-line transformers
- Line-charging compensation
87L Communications Settings – Port 87

Setting

E87CH = number of terminals in scheme and which communications ports are used

Range

2SS = two-terminal serial, single channel
2SD = two-terminal serial, dual redundant channels
3SS = three-terminal serial, local relay slave
3SM = three-terminal serial, local relay master
2E, 3E, 4E = two-, three-, or four-terminal Ethernet card
N = 87L function disabled
Two-Terminal Applications

Single-Channel Application (each end is a master)

Dual-Channel Application (each end is a master)
All relays

- Are masters
- Receive all remote currents
- Run 87L elements
- Trip on differential current
Master Versus Slave Operation

- Failed or Not Installed
- Installed

87L (1) → REM → 87L (2) REM (1)
87L (3) LOC → REM → 87L (1)
87L (3) REM → LOC 87L (2)
TRIP → 87L (1) REM → TRIP
TRIP → 87L (2) REM (2)
TRIP → 87L (3) REM
Master Versus Slave Operation
Master / slave operation

- 87L (2) is master
- 87L (1) and (3) are slaves
- Slaves serve currents and trip via 87DTT signals
Two-Terminal Application Example

Settings
E87CH = 2SD
87PCH = 1
87TADR = 1
87R1ADR = 2

Settings
E87CH = 2SD
87PCH = 1
87TADR = 2
87R1ADR = 1

Channel 1
IEEE C37.94 Fiber
Port 2

Channel 2
IEEE C37.94 Fiber
Port 2

SONET Ring

Direct Fiber

Two masters communicate via direct fiber channel with backup serial channel via SONET ring
SEL-411L Logic

Diagram showing the logic flow, including symbols for analogs, settings, and relay word bits.
### SEL-411L Metering in Per Unit

**87L Communication:** Master  
**87L Function:** Available  
**Stub Bus:** Disabled

#### Local Terminal

<table>
<thead>
<tr>
<th></th>
<th>IA</th>
<th>IB</th>
<th>IC</th>
<th>I1</th>
<th>312</th>
<th>310</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAG (pu)</td>
<td>1.010</td>
<td>1.011</td>
<td>1.009</td>
<td>1.010</td>
<td>0.002</td>
<td>0.003</td>
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<tr>
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<td>120.08</td>
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<td>-22.25</td>
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<tr>
<td>THROUGH (pu)</td>
<td>1.021</td>
<td>1.021</td>
<td>1.021</td>
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<td>0.000</td>
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</table>

#### Remote Terminal 1

<table>
<thead>
<tr>
<th></th>
<th>IA</th>
<th>IB</th>
<th>IC</th>
<th>I1</th>
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<tbody>
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#### Differential

<table>
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<tr>
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<th>IB</th>
<th>IC</th>
<th>312</th>
<th>310</th>
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<tr>
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<td>0.009</td>
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#### Alpha Plane

<table>
<thead>
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<th>87LA</th>
<th>87LB</th>
<th>87LC</th>
<th>87LQ</th>
<th>87LG</th>
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<tbody>
<tr>
<td>k</td>
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<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
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### Settings

#### SEL-411L

<table>
<thead>
<tr>
<th><strong>87 Phase Differential Settings</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>87LPP Pickup value for Phase Differential Element (pu)</td>
</tr>
<tr>
<td>87LPR Radius for Phase Differential Element</td>
</tr>
<tr>
<td>87LPA Block Angle for Phase Differential Element (deg)</td>
</tr>
<tr>
<td>87LPPS Secure Mode Pickup value for Phase Differential Element (pu)</td>
</tr>
<tr>
<td>87LPRS Secure Mode Radius for Phase Differential Element</td>
</tr>
<tr>
<td>87LPAS Secure Mode Block Angle for Phase Differential Element (deg)</td>
</tr>
<tr>
<td>E87LPS Condition for which Phase Differential Element enters Secure Mod</td>
</tr>
</tbody>
</table>

#### SEL-311L

<table>
<thead>
<tr>
<th><strong>87L Settings</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minimum Difference Current Enable Level Settings</strong></td>
</tr>
<tr>
<td>87LPP Phase 87L (Amps secondary)</td>
</tr>
<tr>
<td>87L2P 312 Negative-Sequence 87L (Amps secondary)</td>
</tr>
<tr>
<td>87LGP Ground 87L (Amps secondary)</td>
</tr>
<tr>
<td>CTALRM Ph. Diff. Current Alarm Pickup (Amps secondary)</td>
</tr>
<tr>
<td><strong>Restraint Region Characteristic Settings</strong></td>
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<tr>
<td>87LR Outer Radius</td>
</tr>
<tr>
<td>87LANG Angle (degrees)</td>
</tr>
</tbody>
</table>
Testing the Differentials

- Relay communication
- Pickup points 87LPP, 87L2P, and 87LGP
- Angle 87LANG
- Radius 87LR
- Single-ended test