ECE 525
POWER SYSTEM PROTECTION
AND RELAYING
SESSION no. 3
- If fault in zone 1 for both ends - high speed trip
  - middle 60% or so of the line

- Add communication to allow high speed tripping for all of the line
reactance reach

Resistive reach

\[ \frac{R_{\text{reach}}}{X_{\text{reach}}} < 8 \]
for short lines
Z_{AB} = \frac{V_{AG} - V_{BG}}{I_A - I_B}

Z_{AG} = \frac{V_{AG}}{I_A + k_0 Z_I}

calculate effective impedance compared with measured value

Distance Element

L3 Y/Y

If 2-3 points fall below threshold, need 2-3 points below threshold
Polarizing reference
- Angle reference
- Self polarizing
  \[ V_{AG} = V_{pol} \text{ for } Z_{AG} \]
  \[ V_{A} - V_{B} = V_{pol} \text{ for } Z_{AB} \]

Cross polarization

\[ V_{BC} = V_{pol} \text{ for } Z_{AC} \]
\[ V_{CG} = V_{pol} \text{ for } Z_{AB} \]

with microprocessor or relays
\[ - (V_{B} + V_{C}) \]
memory polarization

$V_1$ - pos sep

$V_{AG}$
Cross polarization or memory polarization causes Mho expansion...
Communication Based

Line current differential protection

\[ \text{Differential Element \ -(87)} \]

\[ I_{op} = |I_1 + I_2 + I_3 + \ldots | \]

\[ I_{RT} = |I_1| + |I_2| + |I_3| + \ldots \]

Normally \[ I_{1} + I_{2} + I_{3} = 0 \]

\[ I_{op} > B I_{RT} \]
100 miles

Imes

Comm channel

Ping - Pong
Role of Communication

- Line protection far faster when can compare with other end of line
- Can locate fault zone
- Need to have adequate back-up in case communication is lost
- Redundancy--does communication go as a result of the fault?

Cybersecurity

- Information technology (IT)
- Operation technology (OT)
  » Industrial control systems
  » Referred to as CS in Table 1.1
- Very different priorities
- NERC Critical Infrastructure Protection
**Future Directions**

<table>
<thead>
<tr>
<th>SAMPLED VALUES</th>
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<tbody>
<tr>
<td><strong>I EC 61850 Process Bus</strong></td>
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<tr>
<td>» Measurements processed at measurement devices and broadcast on substation bus</td>
</tr>
<tr>
<td>» Relays (possibly more general purpose)</td>
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<tr>
<td>– Subscribe to measurements</td>
</tr>
<tr>
<td>– Provides more flexibility and speed</td>
</tr>
<tr>
<td>– Design concerns for reliability and security</td>
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</tbody>
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<th>Phasor measurement based schemes</th>
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<td>– GPS time stamps</td>
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**Introduction**

- Wide area control
- Protection

- Process measurement, filter
- Broadcast on substation bus