Ongoing List of Topics:

- URL: [http://www.ece.mtu.edu/faculty/bamork/EE5223/index.htm](http://www.ece.mtu.edu/faculty/bamork/EE5223/index.htm)
- Labs - EE4224/5224 Lab 3 next week.
- Term Project - teams: ~3, incl. 1 from 5223, signup today!
- Exercise 7 due next Tues 5pm

Today:

- Voltage & Current relationships during faults, §3.5-3.10
  - X/R ratio, dc offset, decay of dc offset
  - Relative angles and magnitudes of all Vs & Is during fault
- Basic connections of directional overcurrent (67) relays.
  - Phase relays - each line current is polarized with $V_{LL}$ from other phases.
  - Ground relay - residual current ($3I_{ao}$) polarized with $V_{\text{broken delta}}$ ($3V_{ao}$)
- Excellent Illustrations: figures 3.7 thru 3.10
67 - Directional O.C.
(Can also have inst. &
time delay versions).

Key: Polarizing input
determines the
directionality of
relay. Can use
either V or I to
polarize.

EE 5210 - Power Systems Protection  Spring 2001
Figure 3.8 (a) Typical three-line connections for phase-fault directional sensing using the 30° unit of Fig. 3.7A. (b) Connections also show the ground fault directional sensing using the 60° unit of Fig. 3.7B. More detail and phasor diagram are shown in Fig. 3.9.
Fault
3Φ

Before Fault

During Fault

Vc
Vb
Va

Ic
Ib
Ia

ZIN.

ZLINE

Trip IF:
- I get big, i.e. above pickup setting
- Ia within "designated" range of angles lagging VAn.
Figure 4.34 Sequence voltages and the voltage at the fault point for the various fault types. Solid faults with $Z_1 = Z_2 = Z_0$ for simplicity. Magnitudes are not to scale.

<table>
<thead>
<tr>
<th>Fault Type</th>
<th>Positive Sequence</th>
<th>Negative Sequence</th>
<th>Zero Sequence</th>
<th>Fault Voltages</th>
</tr>
</thead>
<tbody>
<tr>
<td>a,b,c</td>
<td>v_{a1}</td>
<td>v_{b1}</td>
<td>v_{c1}</td>
<td>Zero at Fault</td>
</tr>
<tr>
<td>a,b</td>
<td>v_{a1}</td>
<td>v_{b1}</td>
<td>v_{c2}</td>
<td>v_{c} = v_{b}</td>
</tr>
<tr>
<td>b,c</td>
<td>v_{a1}</td>
<td>v_{b2}</td>
<td>v_{c1}</td>
<td>v_{a} = v_{c}</td>
</tr>
<tr>
<td>c,a</td>
<td>v_{a1}</td>
<td>v_{b2}</td>
<td>v_{c2}</td>
<td>v_{a} = v_{b}</td>
</tr>
<tr>
<td>a,b,G</td>
<td>v_{a1}</td>
<td>v_{b1}</td>
<td>v_{c2}</td>
<td>v_{a} = v_{b}</td>
</tr>
<tr>
<td>b,c,G</td>
<td>v_{a1}</td>
<td>v_{b1}</td>
<td>v_{c2}</td>
<td>v_{a} = v_{b}</td>
</tr>
<tr>
<td>c,a,G</td>
<td>v_{a1}</td>
<td>v_{b2}</td>
<td>v_{c2}</td>
<td>v_{a} = v_{b}</td>
</tr>
<tr>
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<td>v_{c2}</td>
<td>v_{a} = v_{b}</td>
</tr>
</tbody>
</table>

Figure 4.35 Sequence currents and the fault current for the various fault types. Solid faults with $Z_1 = Z_2 = Z_0$ for simplicity. Magnitudes are not to scale.
the polarity markings diagonally, as shown on the relay schematics in Fig. 3.7.

The reference quantity is commonly called the "polarizing" quantity especially for ground-fault relaying, where either or both current and voltage polarizing is used. The polarity marks (Fig. 3.7) are small plus symbols (+) placed, as illustrated, above one end of each coil, diagonally as shown, or

![Diagram of relays with annotations](image)

**Figure 3.7** Typical directional relay characteristics.