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 should be on track. TA: ssorvala@mtu.edu
- Term Project - teams: ~3, incl. 1 from 5223, begin in week 5.
- Aspen - Remote students: confirm receipt, reasonable deadline.
- Basic connections of directional overcurrent (67) relays.
  - Phase relays - each line current is polarized with \( V_{LL} \) from other phases.
  - Ground relay - residual current (3\( I_{ao} \)) polarized with \( V_{\text{broken delta}} \) (3\( V_{ao} \))
- Show and tell
  - 50/51 relays - electromechanical CO-8; electronic BE1-51C
  - 67 relays - electromechanical KRD; electronic BE1-67N
- Homework #7 (3.4 and 4.1) will be collected after WC
- Term project idea (2-3 sentences) due before WC
- Misc Topics: insulators, BIL, NESC clearances, corona
- Symmetrical Components overview

More today

G1 - Electromech
G2 - Electronic
G3 - µProc
- Reliability
  - Simplicity
  - Component Failure.
    - IC packaging
    - CB design, layout, lamination, cold solder joints.

- Speed
- Selectivity -
## Typical Spacings and Clearances in a Substation

See up-to-date NESC to verify!

<table>
<thead>
<tr>
<th>Voltage Level</th>
<th>Min Conductor Spacing</th>
<th>Min Switch Spacing Ph-Ph</th>
<th>Min L-L Phase Clearance</th>
<th>Min No. Bells at Deadend</th>
<th>Min Cable Size</th>
<th>Min Bus Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>KV (L-L)</td>
<td>BIL (kV)</td>
<td>Cent-Cent</td>
<td>Ph-Gnd</td>
<td>To Grade</td>
<td>Horngap</td>
<td>V Break</td>
</tr>
<tr>
<td>7.5</td>
<td>95</td>
<td>1'-6&quot;</td>
<td>7½&quot;</td>
<td>8'</td>
<td>3'</td>
<td>18&quot;</td>
</tr>
<tr>
<td>15</td>
<td>110</td>
<td>2'</td>
<td>10&quot;</td>
<td>9'</td>
<td>3'</td>
<td>2'</td>
</tr>
<tr>
<td>23</td>
<td>150</td>
<td>2'-6&quot;</td>
<td>12&quot;</td>
<td>10'</td>
<td>4'</td>
<td>2'-6&quot;</td>
</tr>
<tr>
<td>34.5</td>
<td>200</td>
<td>3'</td>
<td>15&quot;</td>
<td>10'</td>
<td>5'</td>
<td>3'</td>
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<tr>
<td>46</td>
<td>250</td>
<td>4'</td>
<td>1'-6&quot;</td>
<td>10'</td>
<td>6'</td>
<td>4'</td>
</tr>
<tr>
<td>69</td>
<td>350</td>
<td>5'</td>
<td>2'-5&quot;</td>
<td>11'</td>
<td>7'</td>
<td>5'</td>
</tr>
<tr>
<td>115</td>
<td>550</td>
<td>7'</td>
<td>3'-7½&quot;</td>
<td>12'</td>
<td>10'</td>
<td>7'</td>
</tr>
<tr>
<td>138</td>
<td>650</td>
<td>8'</td>
<td>4'-1&quot;</td>
<td>13'</td>
<td>12'</td>
<td>8'</td>
</tr>
<tr>
<td>161</td>
<td>750</td>
<td>9'</td>
<td>4'-10&quot;</td>
<td>14'</td>
<td>14'</td>
<td>9'</td>
</tr>
<tr>
<td>230</td>
<td>900</td>
<td>11'</td>
<td>6'-½&quot;</td>
<td>15'</td>
<td>16'</td>
<td>11'</td>
</tr>
<tr>
<td>230</td>
<td>1050</td>
<td>13'</td>
<td>7'-3&quot;</td>
<td>16'</td>
<td>18'</td>
<td>13'</td>
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<tr>
<td>345</td>
<td>1300</td>
<td>15'</td>
<td>8'-5½&quot;</td>
<td>18'</td>
<td>20'</td>
<td>15'</td>
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<tr>
<td>500</td>
<td>1800</td>
<td>25'</td>
<td>12'</td>
<td>---</td>
<td>---</td>
<td>25'</td>
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<td>765</td>
<td></td>
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</tr>
</tbody>
</table>
Corona

Energized Conductor

$E_f$ is largest at surface.

$E \propto \frac{1}{r}$
Arm of T-Structure

Suspension insulation

Cond

4 Bells = 69 KV
"Strain Insulators"
- Deadend connections at Sub.

EE 5210 - Power Systems Protection  Spring 2001
Overcurrent Protection

Fault Source
S.C. Current

Isc = Total Fault Current

Isc is zero (no source)

Possible Strategy:
- Set S0 to pick up for close-in or low-impedance faults.
- Set S1 to take care of high-impedance faults or faults farther out.

EE 5210 - Power Systems Protection  Spring 2001
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
- Look thru Text
- Glover & Sarma Ch.10
- Relays
- Appl. Coord. of Schemes
- New Tech
  - mProc Relays
  - Algorithms (DSP)
  - Optical CTs, VTs
    - Pockels' Effect
- ?? Specific Appl.
- More ideas on following page...
EE 4223/5223 Term Project Ideas:

a. Hardware vs. simulation, or both?
b. Relay tester, lab tests of relays?
c. Extend Matlab work? ASPEN?
d. Type of protection you’re interested in?
   i. Distribution (urban, rural, industrial)
   ii. Transformer (fixed tap, LTC, PS)
   iii. Generator
   iv. Bus
   v. Cap Banks (Shunt or Series)
   vi. Transmission Lines, Cables
   vii. Motors (Induction, Synchronous)
e. Scope of project? Teams of 3-4.
f. Examples of past projects can be looked at. Some topics I can suggest:
   i. Capacitor Bank Protection
   ii. High-Impedance Faults
   iii. Substation Grounding, Grounding Issues
   iv. Small/medium gas-turbine gen protection.
   v. Other ideas - see course web page and click on Useful Web Links.
   vi. New technologies - eg. optical VTs?
   vii. Out of step, load shedding, system separation.
   ix. Relay settings and system coordination.
   x. Pilot schemes.
   xi. Blocking, permissive, overreach, underreach.
   xii. Use of high bandwidth intranet for peer-peer communications among relays.
Blackouts quickly repaired by facilities in key areas

submitted by
News Bureau

MTU facilities staff and Upper Peninsula Power Company personnel restored power to Michigan Tech's main campus at about 4:30 p.m. Wednesday, April 7.

The exact cause of the 3:35 p.m. blackout was unclear Thursday morning, according to Bill McKilligan, manager of facilities operations. "We had a high-voltage power failure, but at this point, we're not sure how it happened," he said.

The power outage was associated with two equipment failures that happened almost simultaneously. Which was the actual cause is still uncertain.

Perhaps the most dramatic was the failure of a large voltage regulator at the UPPCO substation on Phoenix Drive. "It blew up like a roman candle," McKilligan said. The Houghton Fire Department was summoned as a precautionary measure, but the fire was contained and burned itself out.

UPPCO electricians were able to bypass the damaged voltage regulator, restoring power to campus by about 4:30 p.m. Replacement equipment was later shipped up from Green Bay and installed.

In addition, the high-voltage switch gear serving the U.J. Noblet Building also failed. "It's like a light switch, but much bigger," McKilligan said.

"So when it goes out, the current goes to ground, like lightning. The fuses blew all over campus, which is what's supposed to happen. We are isolating the troublesome switch gear and are working to repair the damage."

MTU facilities staff was able to restore full power to the building by about 8:30 p.m., and electricians stayed on the job until after midnight making repairs.

"They came in like a SWAT team yesterday," said Professor Glenn Mroz (SFWP). "We have genetic material that needs to be stored at 80 below 0, and they brought in generators to run freezers. Some had broken in the ensuing brownout after the power went out, and the facilities guys were right in there fixing the compressors and rewiring.

"I was pleasantly surprised at how much they cared and what they can do when the chips are down," he added. "We could have lost millions of dollars worth of research. They were really impressive and a really nice bunch of guys. They went about their jobs very professionally and restored order."

Professor Vincent Chiang agreed. "There was at least a couple million dollars of DNA in those freezers," he said. "And those guys were great—they came in like it was World War II."

The Noblet Building is currently on a "permanent temporary feed."

"UPPCO pitched in, and we are using some wiring from their grid that hadn't been used since the 1980s," Mroz said. "Miraculously, that stuff still works, and that's why we're in business today."
quickly by facilities areas

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This power transformer exploded “like a roman candle” Wednesday afternoon, causing a campus wide blackouts. Some classes were cancelled, but facilities had the power running again within about 45 minutes by some reports.