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 - 5224 - Lab 1 Starts 10am Tues this week
- 2 per lab group. **Min of one grad student per team.**
  - Locals: confirm operation. remote.mtu.edu
  - Online Students - Remote Desktop instructs have been sent

- Aside for the day: CCVTs for voltage measurement + Comm
- Radial Protection (read sections 12.5, 12.6, also G&S Ch.10)
- Basic issues of radial protection, see “Radial Prot” handout
- Type 51 (inverse time-overcurrent relay) settings
- Fuse characteristics
- Instrument transformers: VTs, CTs, CCVTs, MOCTs, etc.
- CTs - pedestal vs. bushing
- CT saturation & accuracy, ratios, multi-ratio CTs
$Z_c = 280 - 400 \, \Omega$

(Typ: 300 - 350Ω)

Probs

- Ice
- Mist
- Rain

PLC 30 - 450 KHz

Line Tuning Unit

LTU

Comm

≈ 300 Ω

50 Ω

$100 \, \Omega @ 60\, \text{Hz}$

HV Cond

Lower unit of CCVT

115V

67V 115V

367V 115V

"polarisation"
Simplest - Share 1 or 2 bits of control logic.
Complex - Real-time control (10 Gb/s), intranet.
Radial Protection

Dist. Sub.

34.5 - kV, 41.6 - kV, 69 - kV, 115 - kV

50/51/79

R

Recloser (CB w/ relays)

S

Cust 1

F1

F2

F35

Cust 2

Sectionalizers

- Not all faults are permanent. Think winds, squirrels, birds, etc.

- Must wait approximately 30 cycles or so for air to de-ionize (after de-energizing).

- "Fast trips" first.

- Reclose.

Give up? => Slow trip, fuse blows
F2

Fuse Curves

Fast trips \Rightarrow \text{prevent melt damage.}

Slow trips \Rightarrow \text{long enough to clear.}

Fast trip < t_1,
Slow trip > t_2

I_{sc} \text{ for fault at Cust. 2}
Types of Faults

3 phase: 2-370
L-L: 8-1070
L-L-G: 10-1770
L-G: 70-8070

Radial Protection

NEXT: Read Radial Protection posted in Week 2!
Distribution Protection -

System components:

34.5 kV
41.6 kV
69 kV or 115 kV
13.8 kV
3.5 kV
12.47 kV

Fuse, CB, or circuit switcher

Recloser

Sectionalizers

Fuse

Customer 1

Customer 2

Note that distribution systems are always radially connected!

Recloser - combined relay/CT/circuit breaker. Usually attempts 2-4 recloses following a fault.

Sectionalizer - switch that automatically disconnects after set number of fault/trip events. Set to disconnect after one less than max reclose attempts. Ex: 4 reclose attempts -> lockout sectionalizer after 3 fault surges.

Fuses: See p. [186] of text

Must coordinate fuse sizes and time characteristics so downstream fuse clears before upstream fuse melts.

Note: Due to line impedance, fault at "a" draws less current than fault on b. (Further "out" on system, lower IFAULT)
One-line Symbols:

- Circuit Breaker (High Voltage)
- Air-Break Circuit Breaker (Low Voltage)
- Fused Disconnect Switch
- Fused cutout
- Disconnect Switch
- Air-Break Switch w/arc restriction
- Circuit Switcher

Vaccum interrupter trips first, then switch opens. Can't interrupt high fault currents like CBs but cheaper. Often used on HV side of transformer. Can close & open on full load current also, so provides function of load-break switch as well.
General goal: - closest device upstream from fault must clear.
- Minimize portion of system that goes black, (Zero if possible).

Ex: Permanent Fault at a.

Recloser - 2 fast, 1 slow
Sectoimalizer &2 set for lockout, 2 fast
2nd reclose at 2
3rd reclose success!

Set sectoimalizer at about 0.8 of min fault current it would ever "see" downstream.

About 80% of the time, the first fast reclose restores the system, i.e. fault was temporary - squirrel, bird, wind knocking wires together, trees.

About 10% of the time, the 2nd reclose will succeed, assuming the first did not.

The "fast trips" occur fast enough to prevent melting of downstream fuses. The delayed trip allows fault to persist long enough to clear fuse.
Recloser can also lock out, if downstream coordination is botched or if fault is "close in", i.e. if \( 50/51 \) relay is used in recloser, 51 trip would allow reclose sequence but 50 (instantaneous) trip would not.

Various reclose strategies are used. Each utility has their preferences. Most common:

\[
\begin{align*}
\text{1 fast} & \quad \frac{1}{2} \text{ sec} \\
\text{1 slower (several seconds)} & \quad 2 \text{ seconds} \\
\text{1 long delay (5-10 seconds)} &
\end{align*}
\]

\[
\begin{align*}
\text{2 fast} & \quad < \frac{1}{2} \text{ sec} \\
\text{2 slow} & \quad 5-10 \text{ sec} \\
\text{30 sec} &
\end{align*}
\]

After successful reclose sequence, the recloser will "reset" itself after a certain time. The sectionalizer’s counter will also reset, provided it was not driven to lockout.

Note: Reclosers are bad in case of human contact. Utilities always disable reclose if line crew is doing live line work! Human contact or downed lines are bad.