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 today 7pm
- Software - Aspen 2011, V11.10, remote.mtu.edu
  - Locals: confirm operation.
  - Online Students - Remote Desktop instruct being 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
CCVT

\[ V_{LD} = \frac{115}{\sqrt{3}} \text{ KV} \]

HV Bus Bar

4-10KV

115V
$Z_e = 280 - 400 \Omega$
(Typ: 300-350Ω)

Probs
- Ice
- Mist
- Rain

PLC 30-450 KHz

CCVT
$x_e = \frac{1}{2}\frac{V}{I}$

Line Tuning Unit

Lower Unit of CCVT

67V \{ 115V
367V \{ 115V

Comm ~300Ω

100Ω @ 60Hz

5Ω
Simplest - share 1 or 2 bits of info as part of control logic.

Complex - Real-time control, intranet (10 Gbs).
Radial Protection

Dist. Sub.

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

50/51/79

Recloser (CB w/ relays)

F1

F2 < F35

Cust 1

Secionalizers

Cust 2

- Not all faults are permanent. Wind, squirrels, birds, etc.

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

- Fast trips first.

- Reclose.

Give up? => Slow trip, fuse blows
Fast trip < t₁
Slow trip > t₂

Isc for fault at Cust. 2

Fast trips ➞ prevent melt damage.
Slow trips ➞ long enough to clear.

Fuse Curves

F2

Max Clear

min melt

Isc
3 phase: 2-3%

L-L: 8-10%

L-L-G: 10-17%

L-G: 70-80%

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

System components:

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

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:

- Control/termination cabinet, used for plan view drawings.

- 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

Vacuum interrupter trips first, then switch opens. Can't interrupt high fault currents like CB, 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
Sectolizer #2 set for lockout at 2.

Fast trip → fast trip → delay trip →
First reclose → 2nd reclose → 3rd reclose - success!
wait → min

Recloser locks out if fault persists.

Set sectolizer 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:

- 1 fast \( \leq \frac{1}{2} \) sec
- 1 slower (several seconds) 2 seconds
- 1 long delay \((5-10)\) seconds

- 2 fast \( \leq \frac{1}{2} \) sec
- 2 slow \( 5-10 \) sec \(30\) sec

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.