Ongoing List of Topics:

- URL: http://www.ece.mtu.edu/faculty/bamork/EE5223/index.htm
- Labs - 5224 - Lab 2 Starts Wed this week
  - Locals: confirm operation.
  - 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
Simplest - share 1 or 2 bits of info as part of control logic.

Complex - Real-time control, intranet (10 Gbps).
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 3

Cust 1

Cust 2

Sectionalizers

- 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 $< t_1$
Slow trip $> t_2$

Fuse Curves

Fast trips $\Rightarrow$ prevent melt damage.
Slow trips $\Rightarrow$ long enough to clear.

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

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:

- 34.5 kV
- 41.6 kV
- 69 kV
- 115 kV
- RECLOS
- DIST XFM R 13.8 kV
- 3/3.47 kV
- FUSE or circuit breaker

Note that distribution systems are always radially connected!

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**Reclose**: 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:

or

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
Seconalizer #2 set for lockout at 2.

First reclose
2nd reclose
3rd reclose - success!

Recloser locks out if fault persists.

Set sectionalizer 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 (5 sec) 1/2 sec
2. Slower (several seconds) 2 seconds
3. Long delay (5-10 seconds)

2. Fast < 1/2 sec
2. Slow = 5-10 sec
3. Slow = 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.