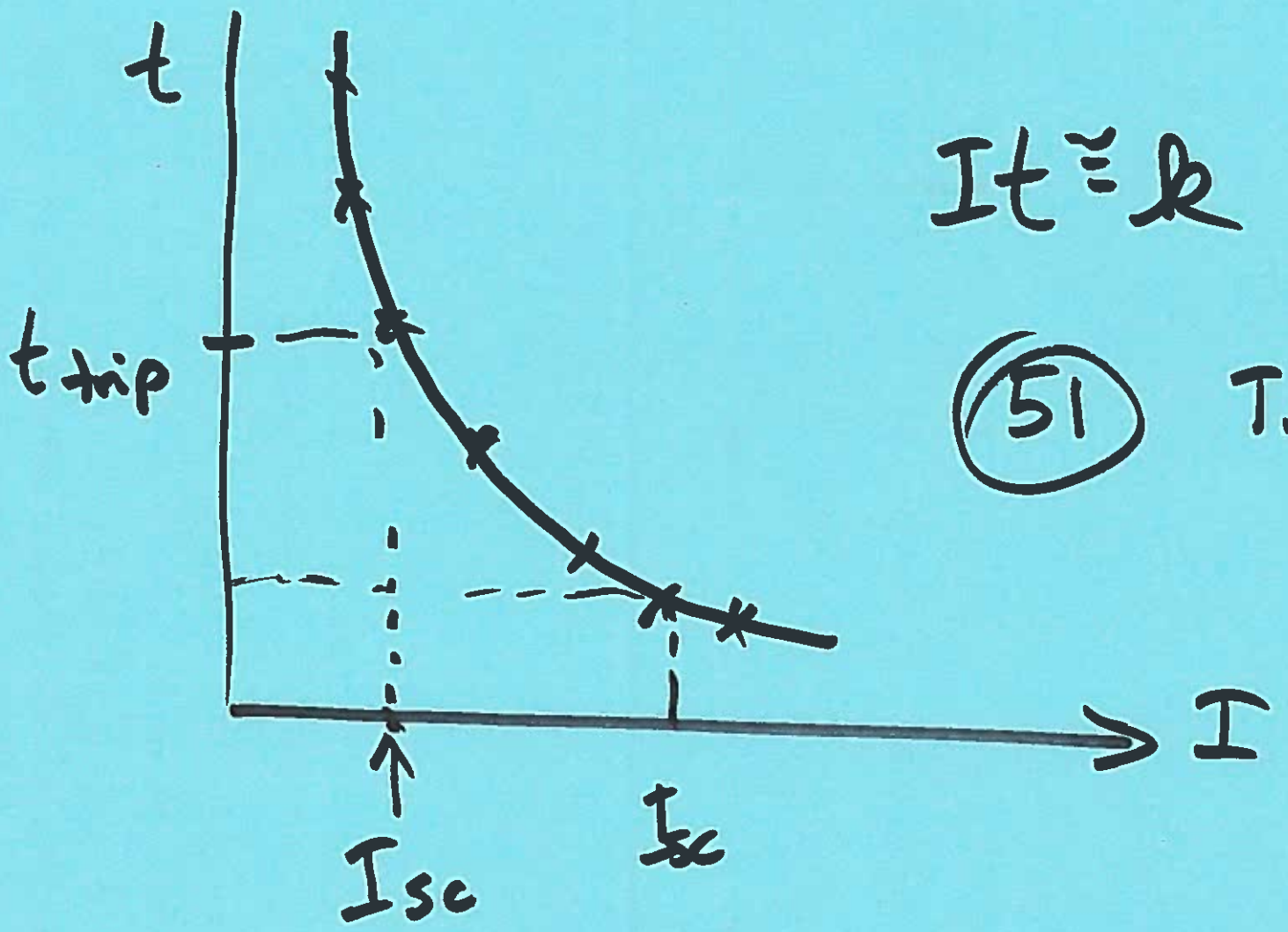
EE 5223 - Lecture 7 Mon Jan 23, 2022

Ongoing List of Topics:

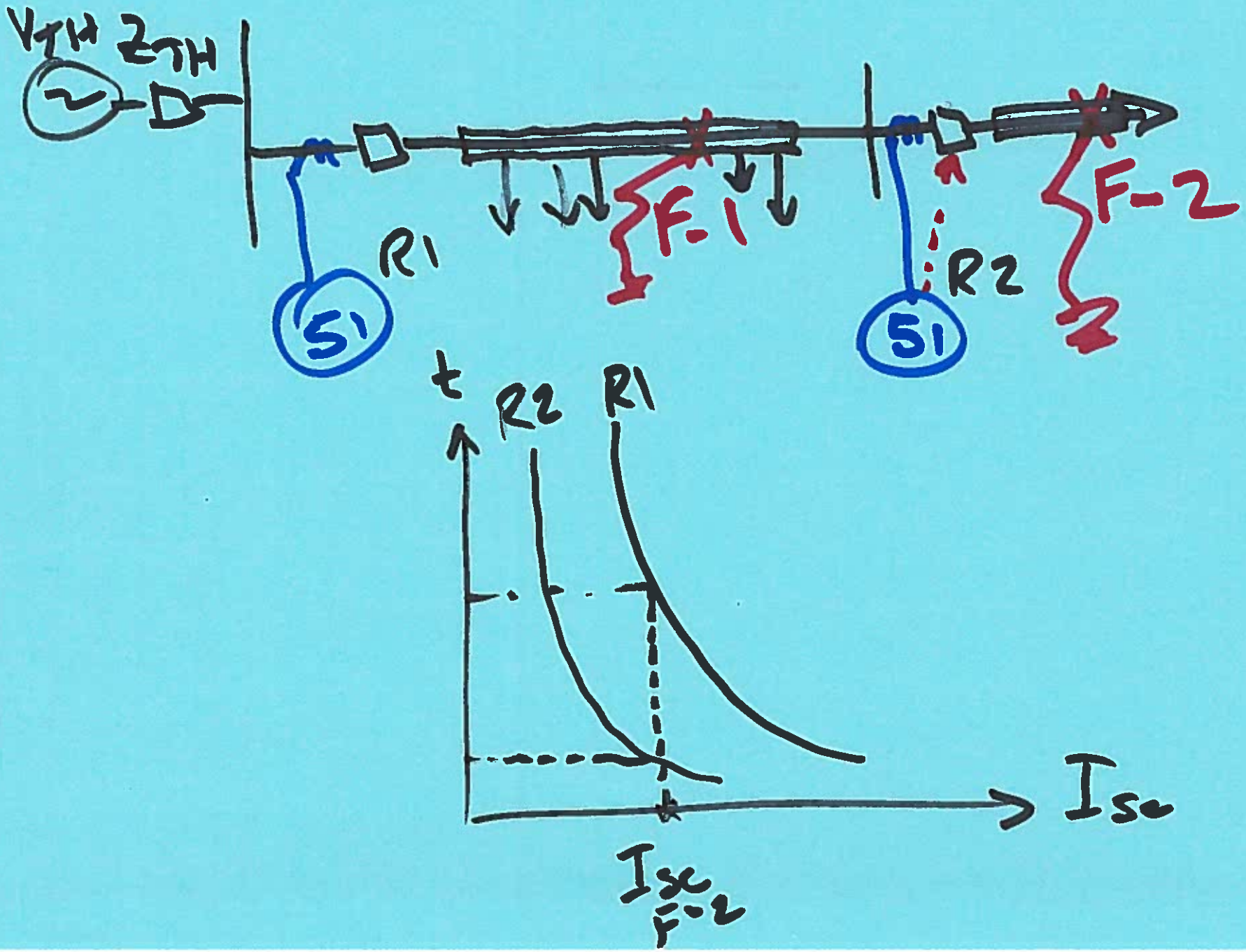
- URL: http://www.ece.mtu.edu/faculty/bamork/EE5223/index.htm
- Labs - 5224 - Lab 1 Starts 10am Wed this week
- 1 per lab group. Prelab with others. Get to know grad students!
- Software - Aspen V15.6, 2022 (in process of being upgraded).
  - Locals: confirm operation. remote.mtu.edu
  - Online Students - Remote Desktop instructs have been sent

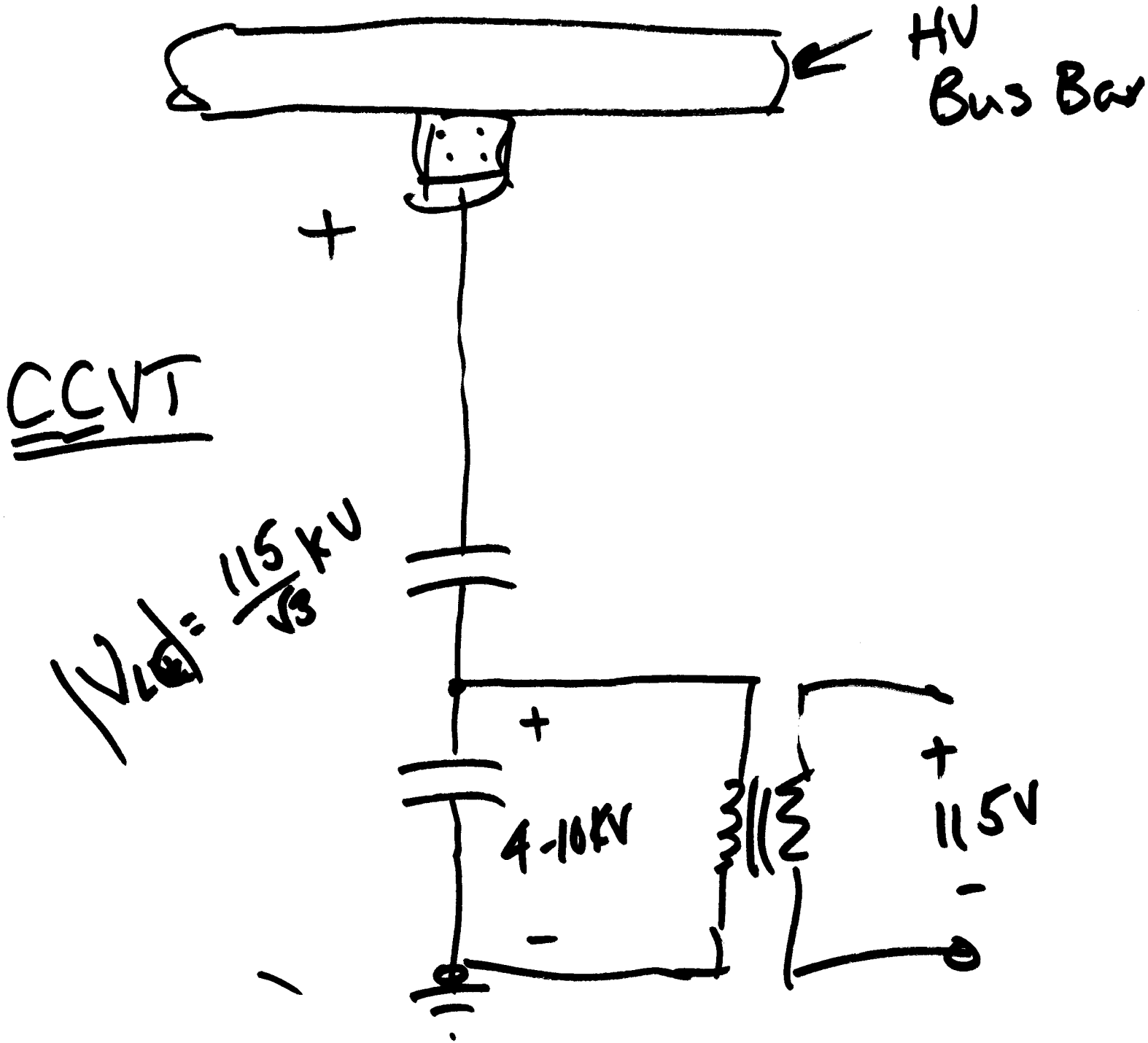
- Aside for the day: CCVTs for voltage measurement + Comm
- Radial Protection (read sections 12.5, 12.6, also G&S Ch.10)
- Basic issues of radial protection, see “Radial Prot” handout
- Type 51 (inverse time-overcurrent relay) settings
- Fuse characteristics
- Instrument transformers: VTs, CTs, CCVTs,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

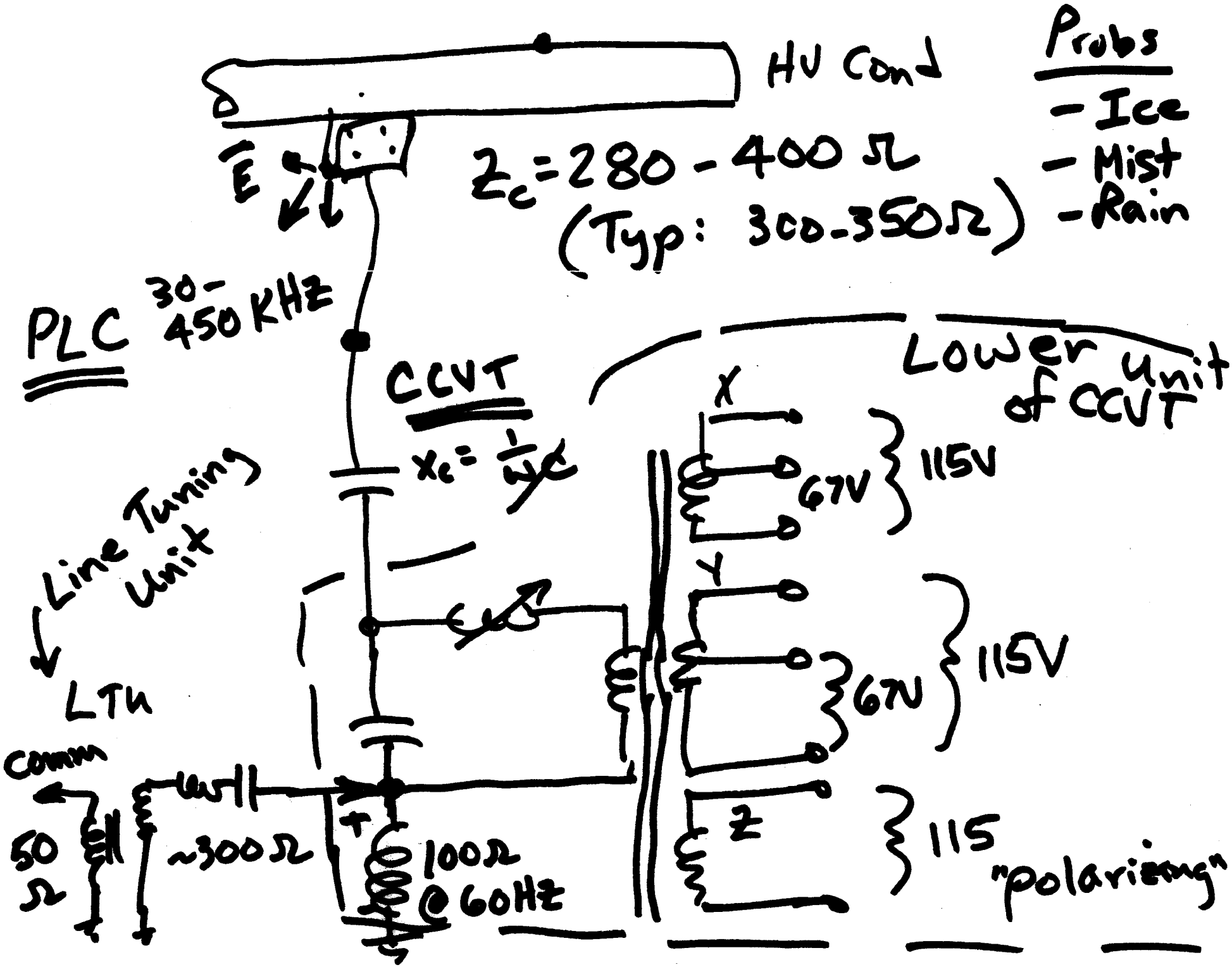


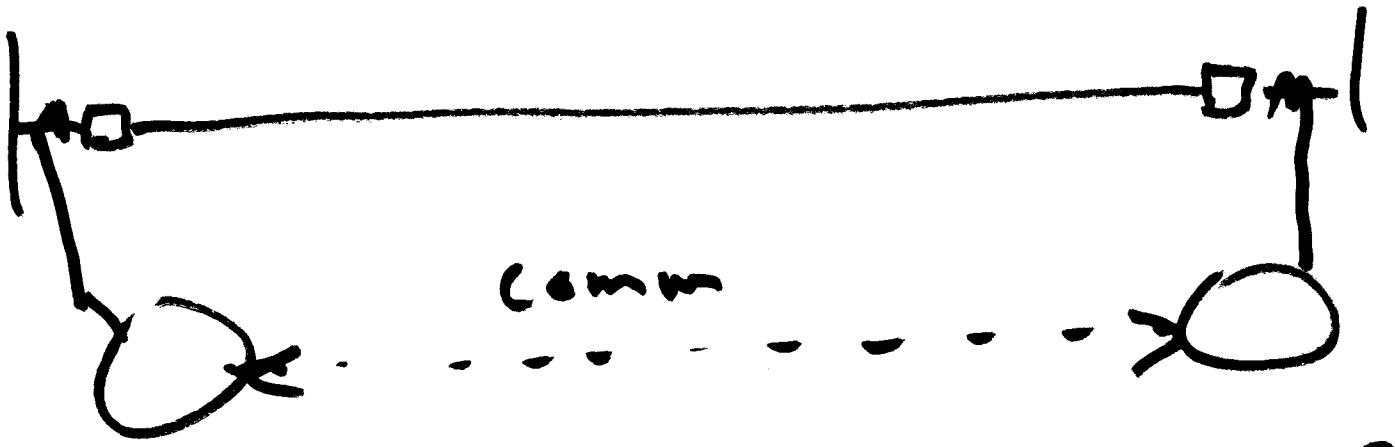
$It \cong k$

(51) T.O.C.


V_{TH}
Z_{TH}
F-1
F-2
R1
R2
S1
S1
t
R2
R1
I_{sc}
$I_{sc_{F-2}}$


HV
Bus Bar
+
CCVT
$|V_{LG}| = \frac{115}{\sqrt{3}}$ kV
+
4-10kV
-
+
115V
-

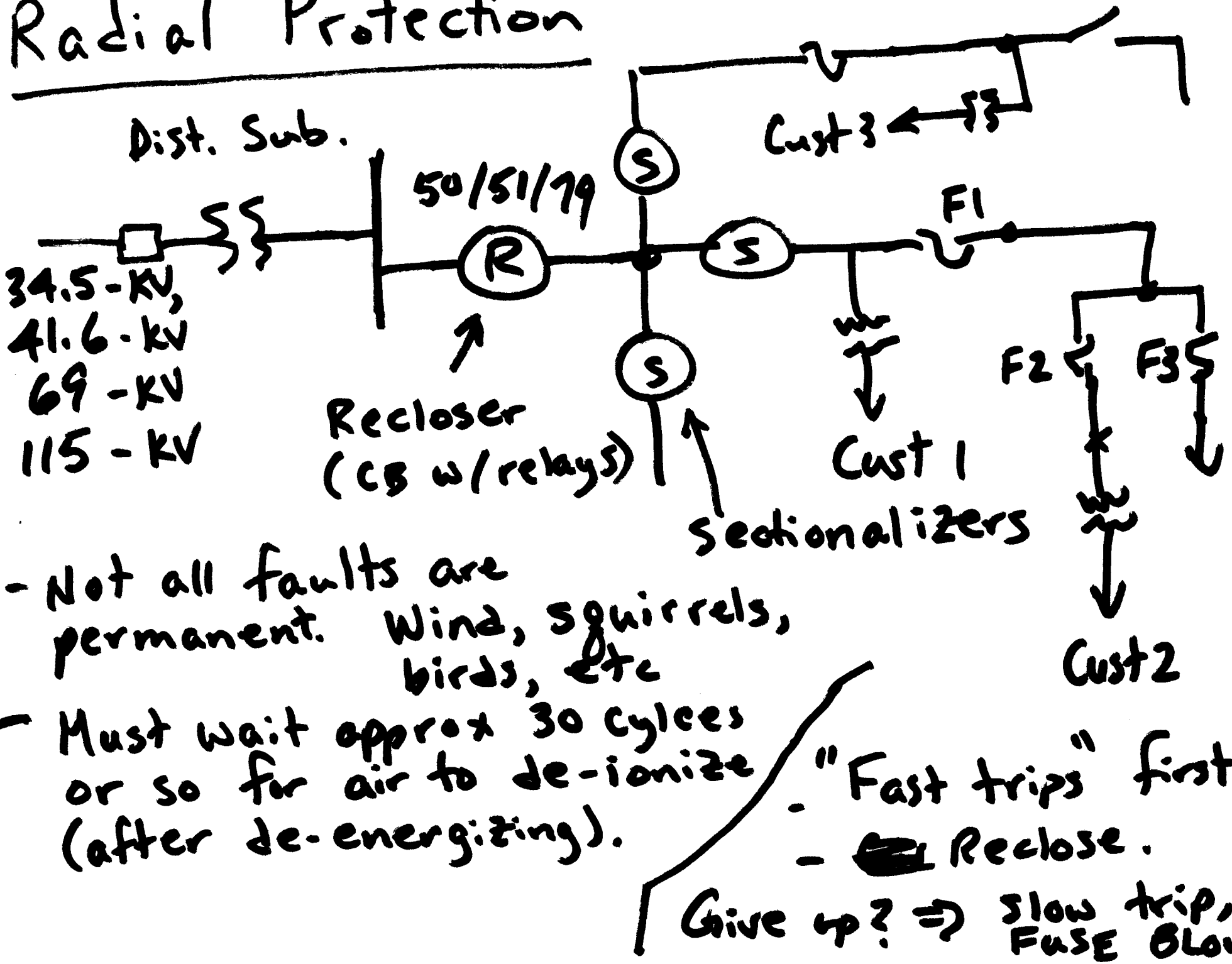

HV Cond
Probs
- Ice
- Mist
- Rain
E
Z_c = 280 - 400 Ω
(Typ: 300-350Ω)
PLC
30-450 KHz
CCVT
$X_c = \frac{1}{\omega C}$
Lower Unit of CCVT
X
67V
115V
Y
67V
115V
Z
115
"polarizing"
Line Tuning Unit
LTU
Comm
50 Ω
~300Ω
100Ω @ 60Hz



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

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

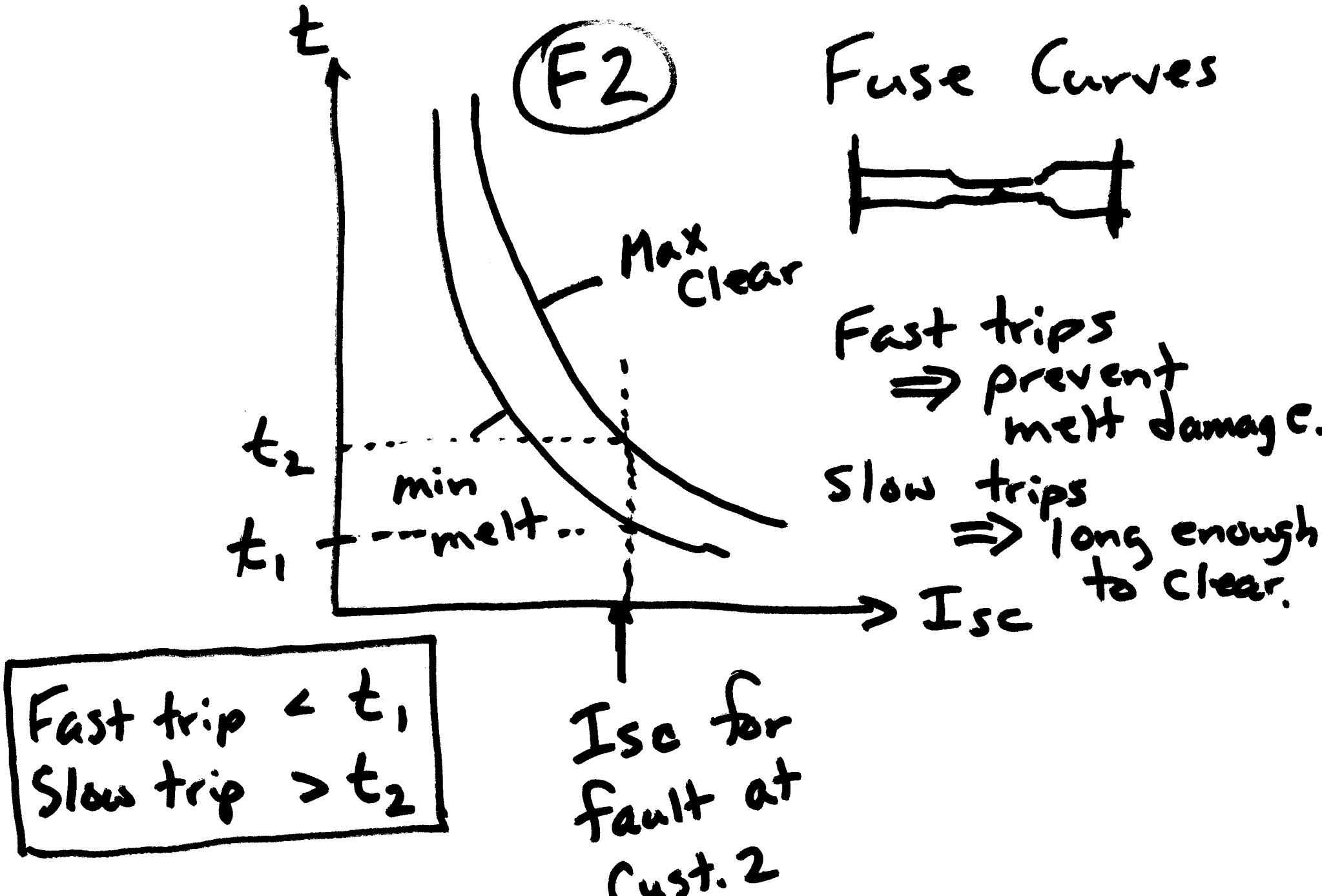
Radial Protection



- 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


t
F2
Fuse Curves
Max Clear
Fast trips
⇒ prevent
melt damage.
t_2
min
melt
t_1
Slow trips
⇒ long enough
to clear.
I_{sc}
Fast trip < t_1
Slow trip > t_2
I_{sc} for
fault at
Cust. 2

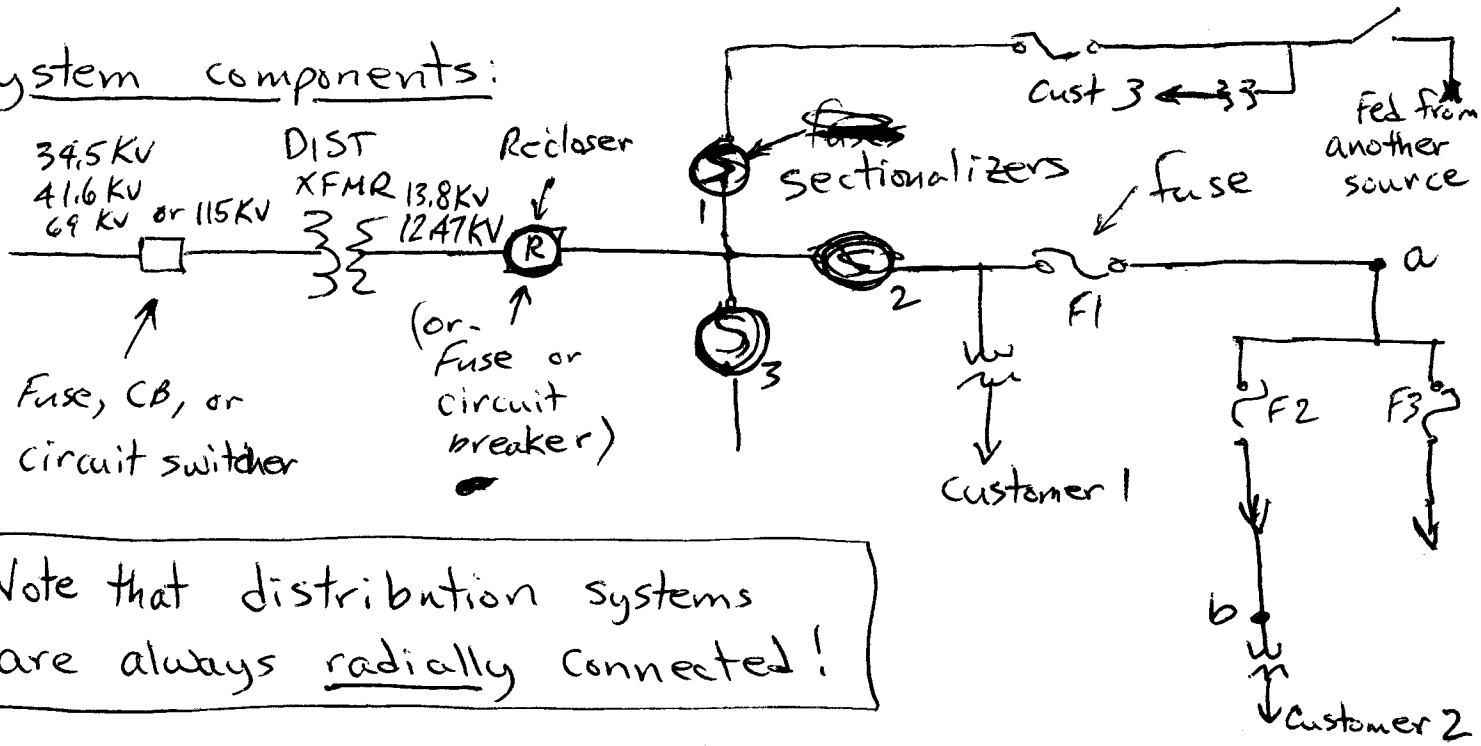
Types of Faults

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:



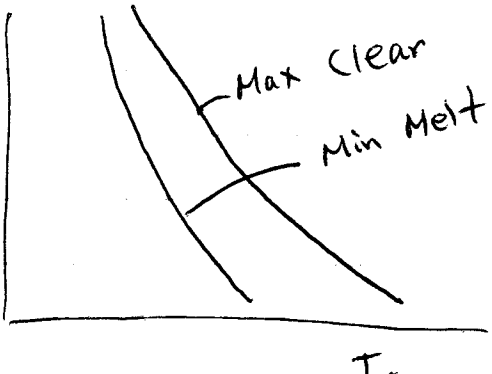
Note that distribution systems are always radially connected!

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.

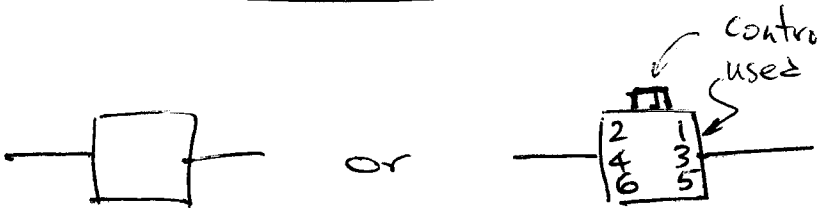
Fuses: See p. 186 of text

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



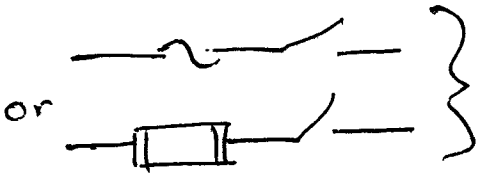
Note: Due to line impedance, fault at "a" draws less current than fault on b. (Further "out" on system, lower I_{FAULT})

One-line Symbols:

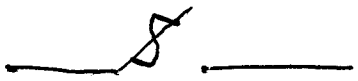


CIRCUIT BREAKER (High Voltage)

Air-Break Circuit Breaker (Low Voltage)



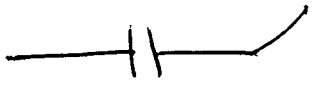
Fused Disconnect Switch



Fused cutout

Disconnect Switch

Air-Break Switch w/arc restrictor

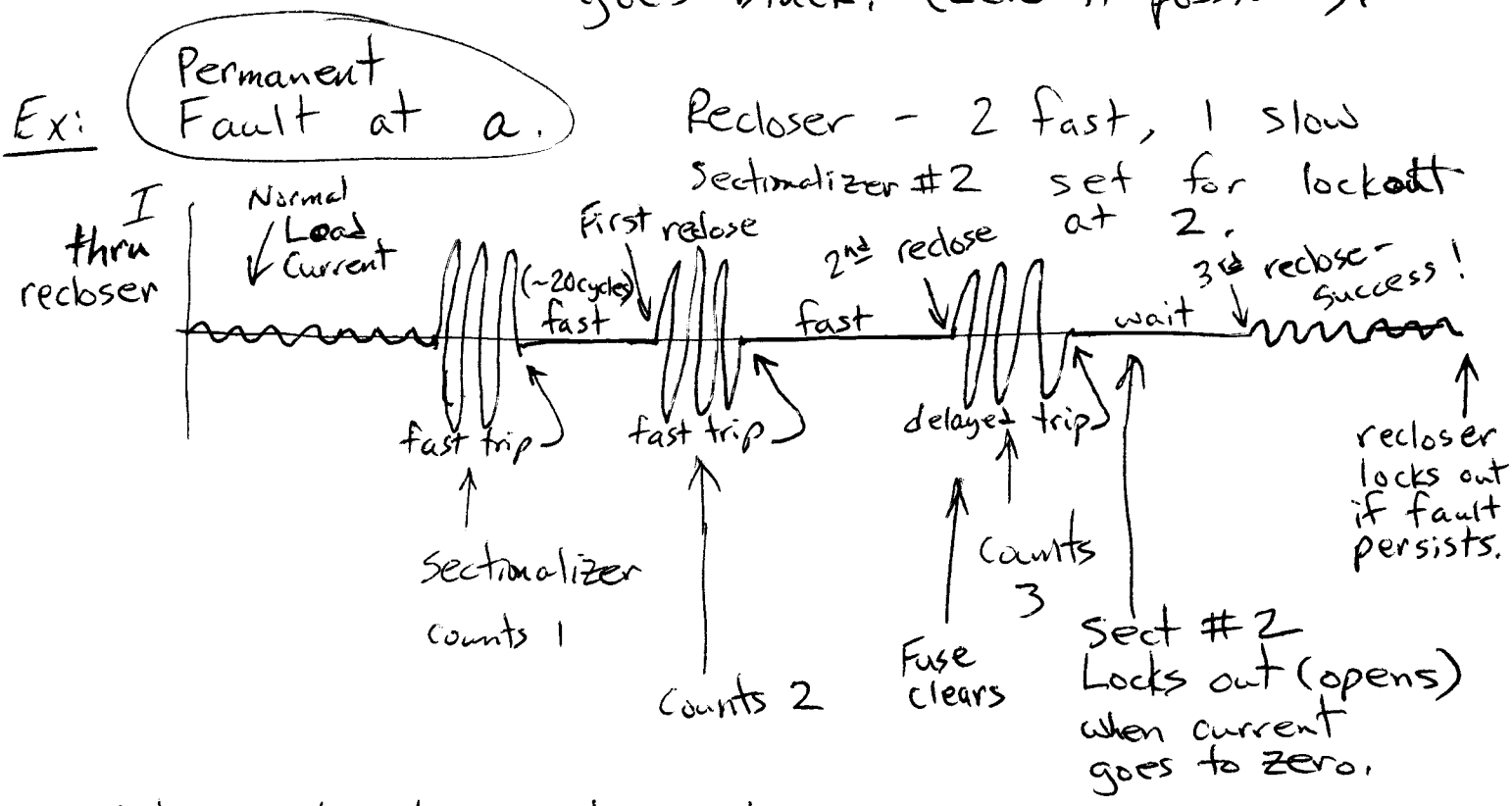


Circuit Switcher

↑ 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.



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 ½ sec
- 1 slower (several seconds) 2 seconds
- 1 long delay (5 – 10 seconds)

- 2 fast — ½ sec / 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.