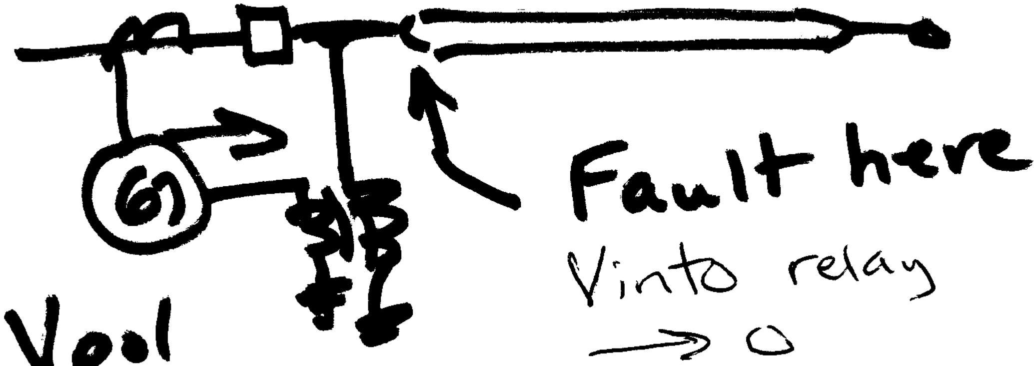
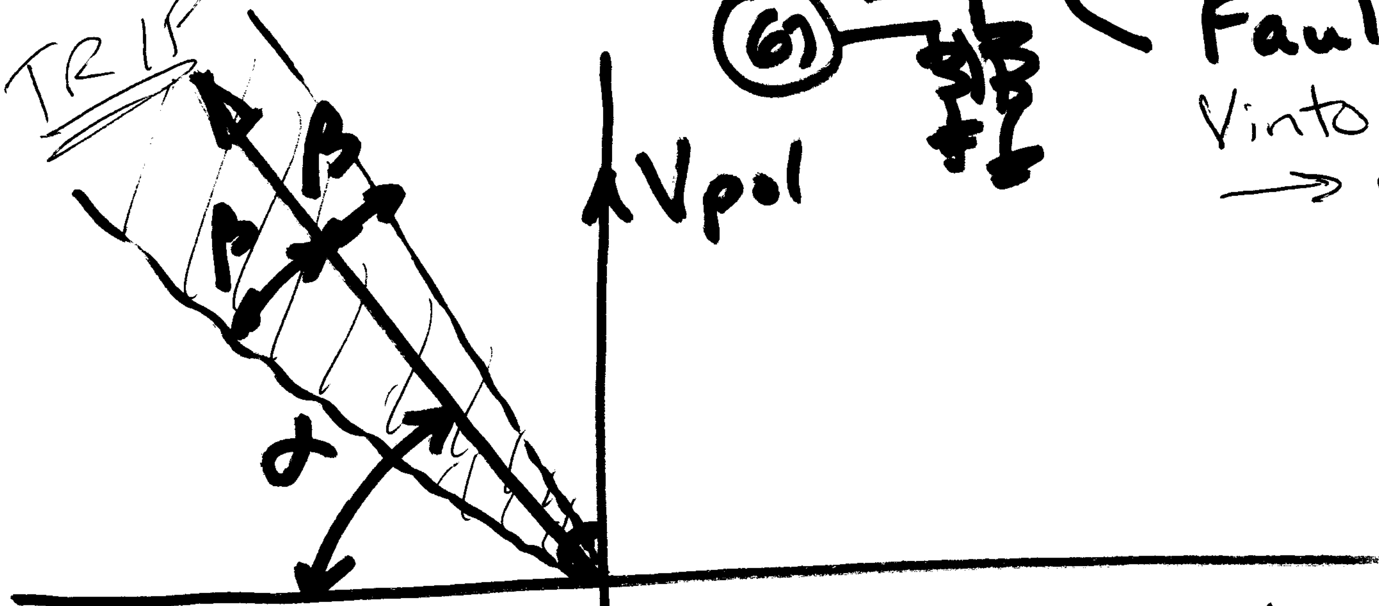
EE 5223 - Lecture 19 Mon Feb 22, 2023

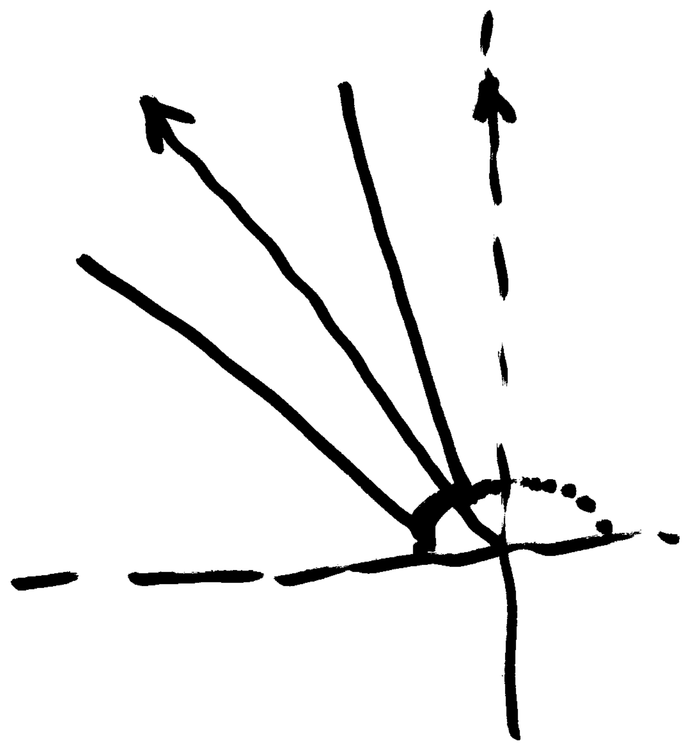
Ongoing List of Topics:

- URL: https://pages.mtu.edu/~bamork/EE5223/
- Term Project - last few proj/teams being firmed up.
  - E-mailed in, ask that they be uploaded to Canvas.
- Homework #8 - directional overcurrent protection
  - Phase impedances (a,b,c) vs. sequence impedances (0,1,2)
  - EE4222 text (Glover & Sarma) gives good explanation, §8.2.
- Next Homework - sequence networks, transformer phase shifts
- Symmetrical Components overview issues for today.
  - Sequence networks, 3-winding transformers, §4.14, Prob 4.4.
- Protection fundamentals (cont'd):
  - Distance relaying fundamentals: §6.5.6, §6.5.7
  - Bus diff, xfmr diff, synch check, capacitor banks, generators, motors, etc. (take a quick run through Ch.6, also Glover & Sarma, Ch.10).

67 Relay:



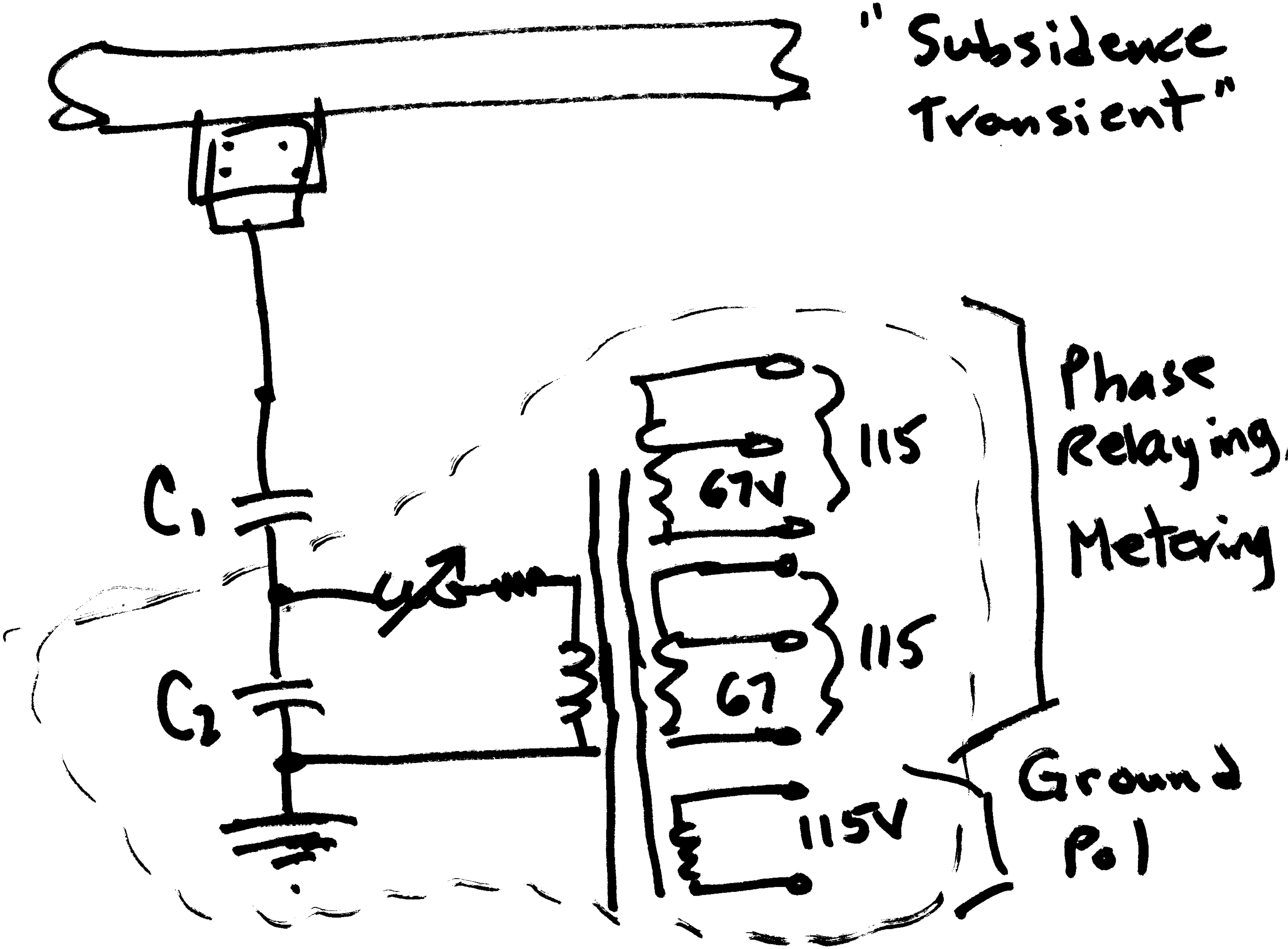


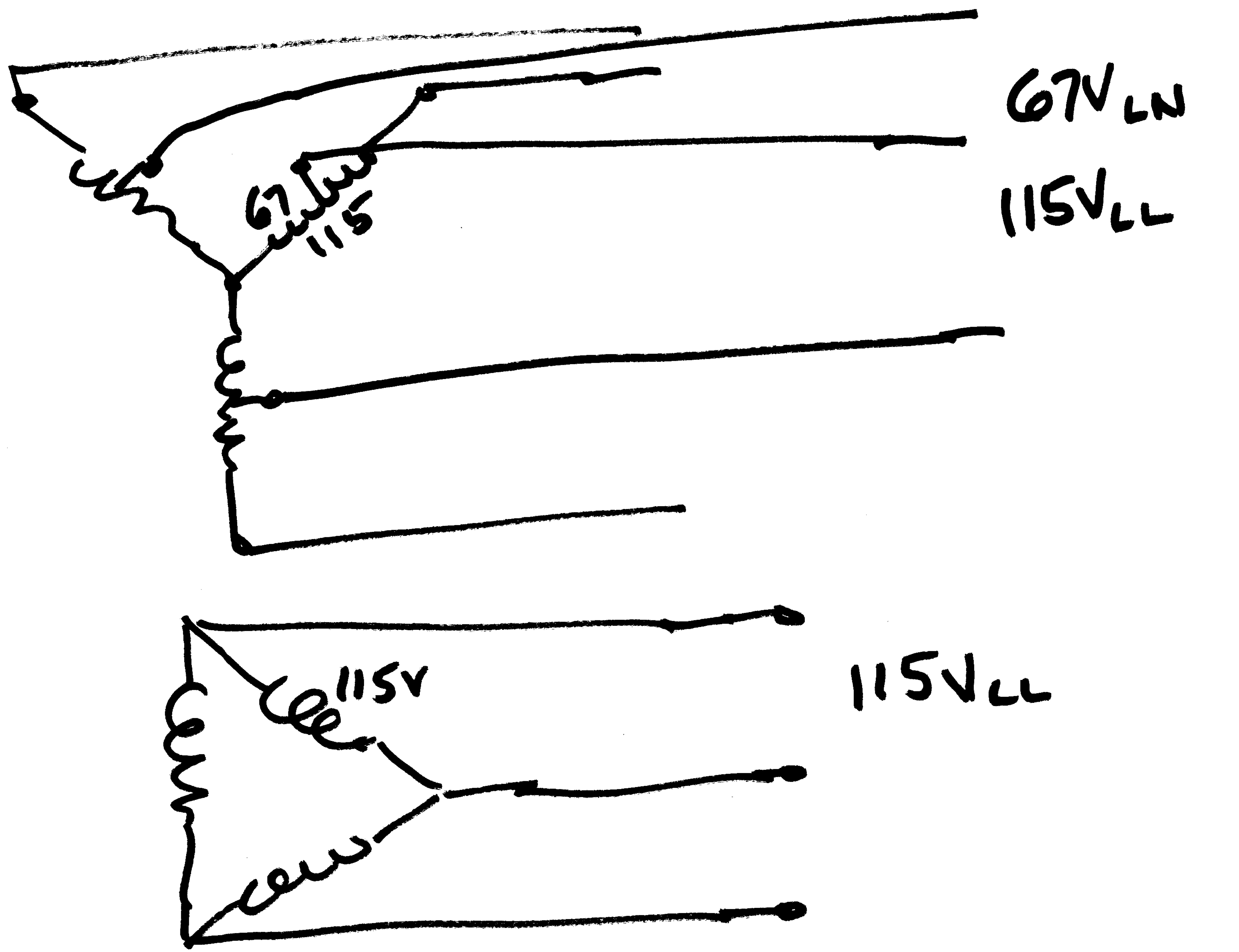


Solution:

"Memory" feature
- Holds angle of last-known Vpol.

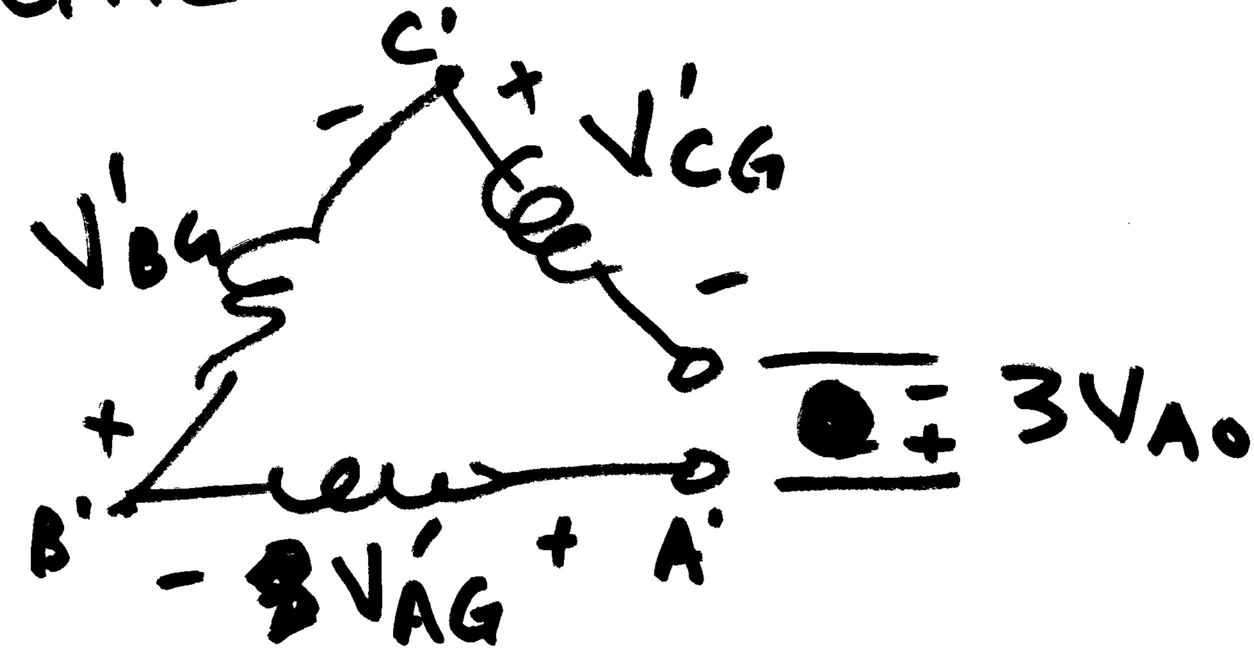
Voltage Measurement from CCVT





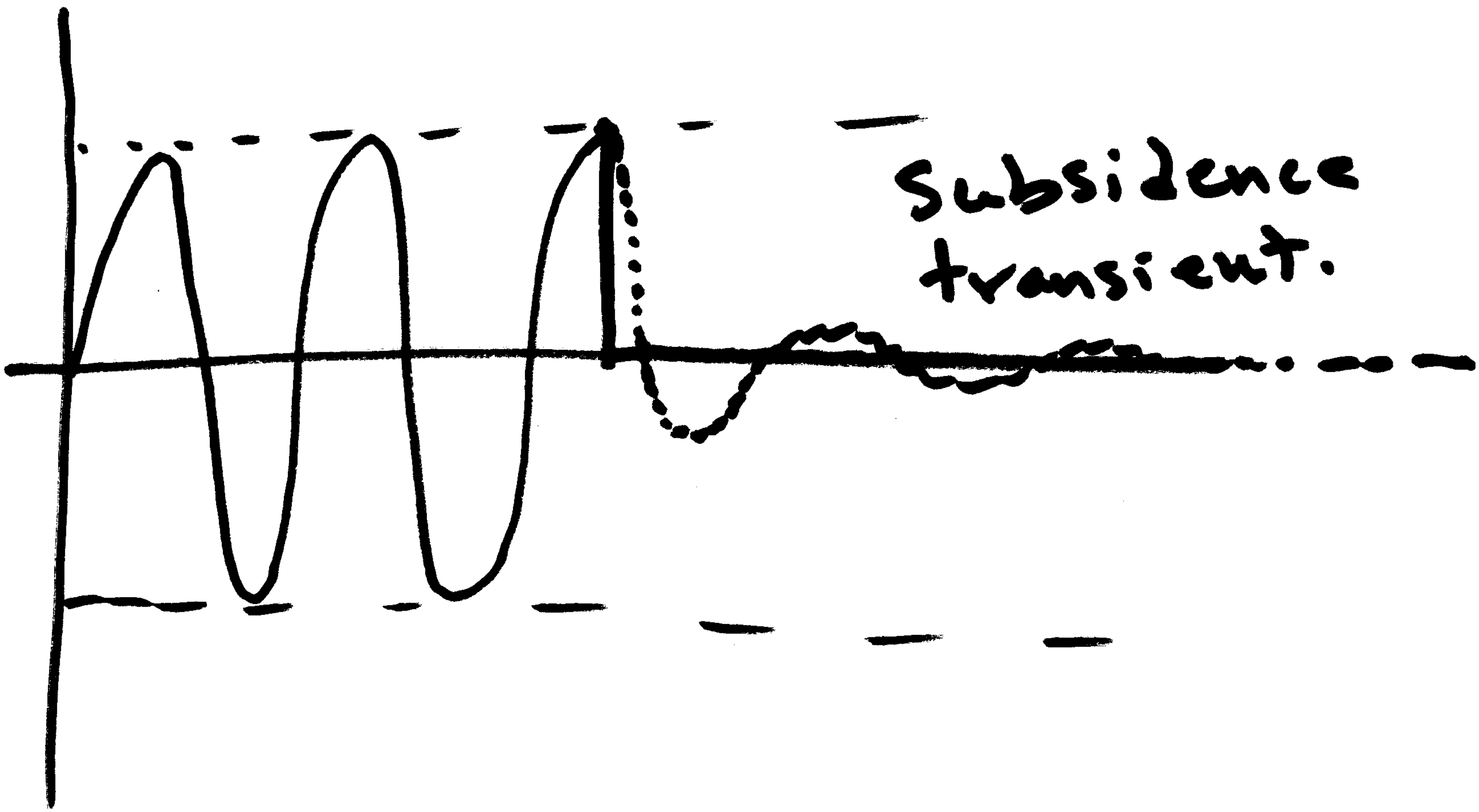
67
115
67V LN
115V LL
115V
115V LL

Gnd Polarization



$$3V'_{AO} = V'_{AG} + V'_{BG} + V'_{CG}$$

Close-in fault, LG at peak voltage



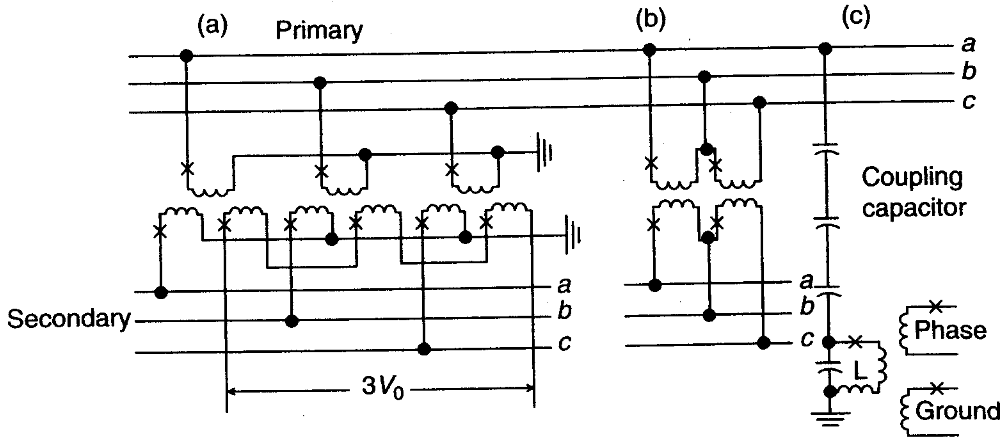


FIGURE 5.18 Typical voltage sources for relays: The secondary circuits for the coupling capacitor voltage transformer (CCVT) device are simplified schematics, for concept only. (a) secondary phase-and-ground voltage with three double secondary VTs connected phase-to-ground; (b) secondary phase voltage with two single secondary VTs connected open delta; (c) secondary phase-and-ground voltage with three CCVTs connected phase-to-ground. [Only one phase shown, *b* and *c* phases duplicate with secondaries connected as in (a).]

Protective relays utilizing voltage are usually connected phase-to-phase, so the transformers are normally rated 120 V line-to-line. Taps may be provided to obtain either 69.3 V or 120 V line-to-neutral. When available, double secondaries provide the means of obtaining zero-sequence voltage for ground relays (see Figure 5.18a). If only a single transformer secondary winding is available, an auxiliary wye ground-broken delta auxiliary VT can be connected to the secondary *a*, *b*, and *c* bus of Figure 5.18a for $3V_0$, similar to the connections shown. A typical example is shown in Figure 1.10. CCVTs commonly have double secondaries for both phase and $3V_0$ voltages (see Figure 5.18c).

Three VTs or three CCVTs, such as shown in Figure 5.18a and c, pass positive-, negative-, and zero-sequence voltage. The open-delta connection of Figure 5.18b will pass both positive- and negative-sequence voltage, but not zero-sequence voltage.

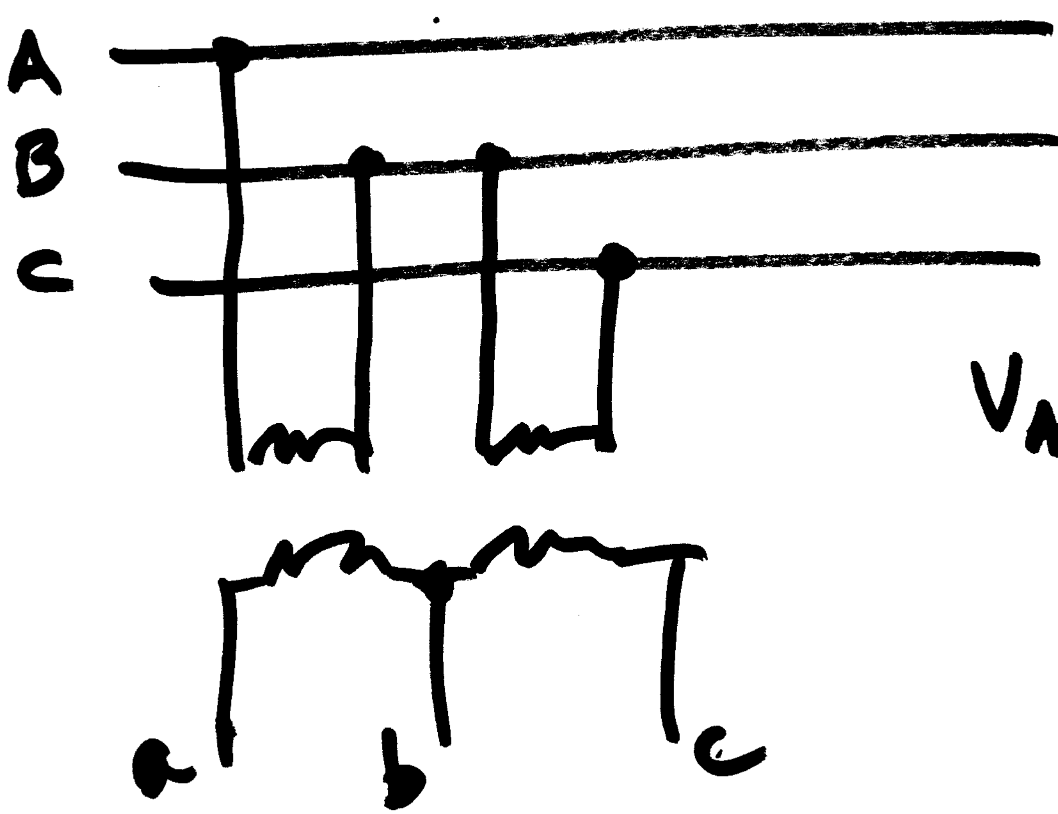
VTs are used at all power system voltages and are usually connected to the bus. At about 115 kV, the CCVT type becomes applicable and generally more economical than VTs at the higher voltages. Usually, the CCVTs are connected to the line, rather than to the bus, because the coupling capacitor device may also be used as a means of coupling radio frequencies to the line for use in pilot relaying. This is discussed in Chapter 13.

Either type of transformer provides excellent reproduction of primary voltage, both transient and steady-state, for protection functions. Saturation is not a problem because power systems should not be operated above normal voltage, and faults result in a collapse or reduction in voltage. Both have ample capacity

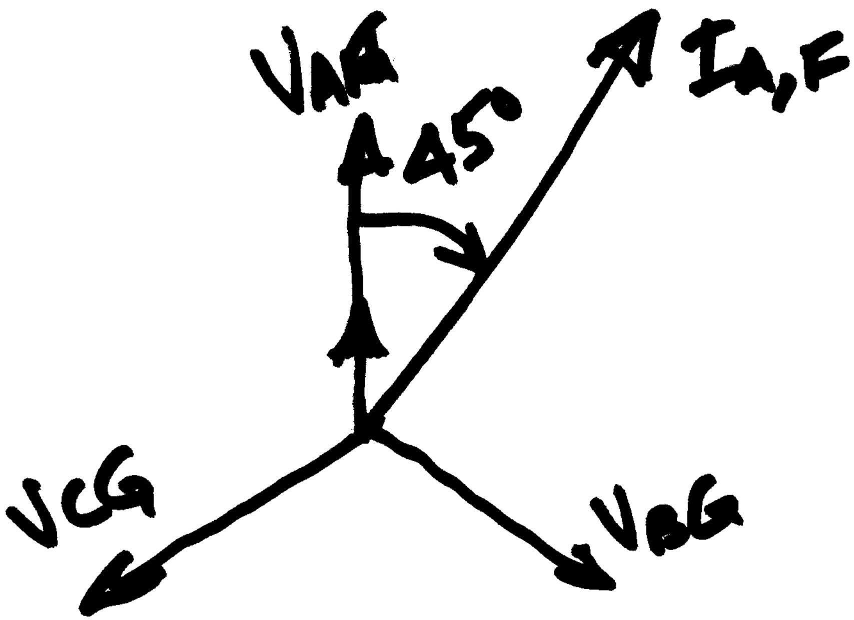
$$V_{AG} = V_{A1} + V_{A2} + V_{A0}$$

$$V_{BG} = V_{B1} + V_{B2} + V_{B0}$$

$$V_{CG} = V_{C1} + V_{C2} + V_{C0}$$

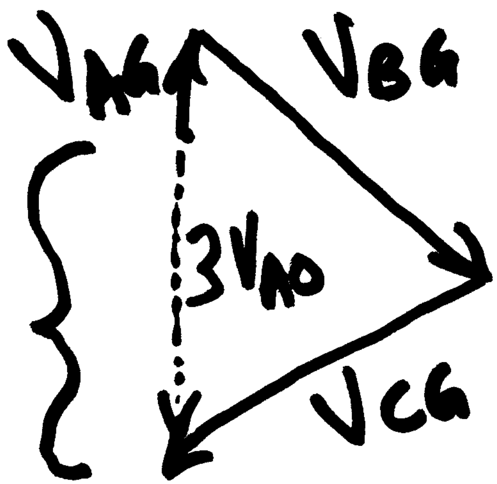


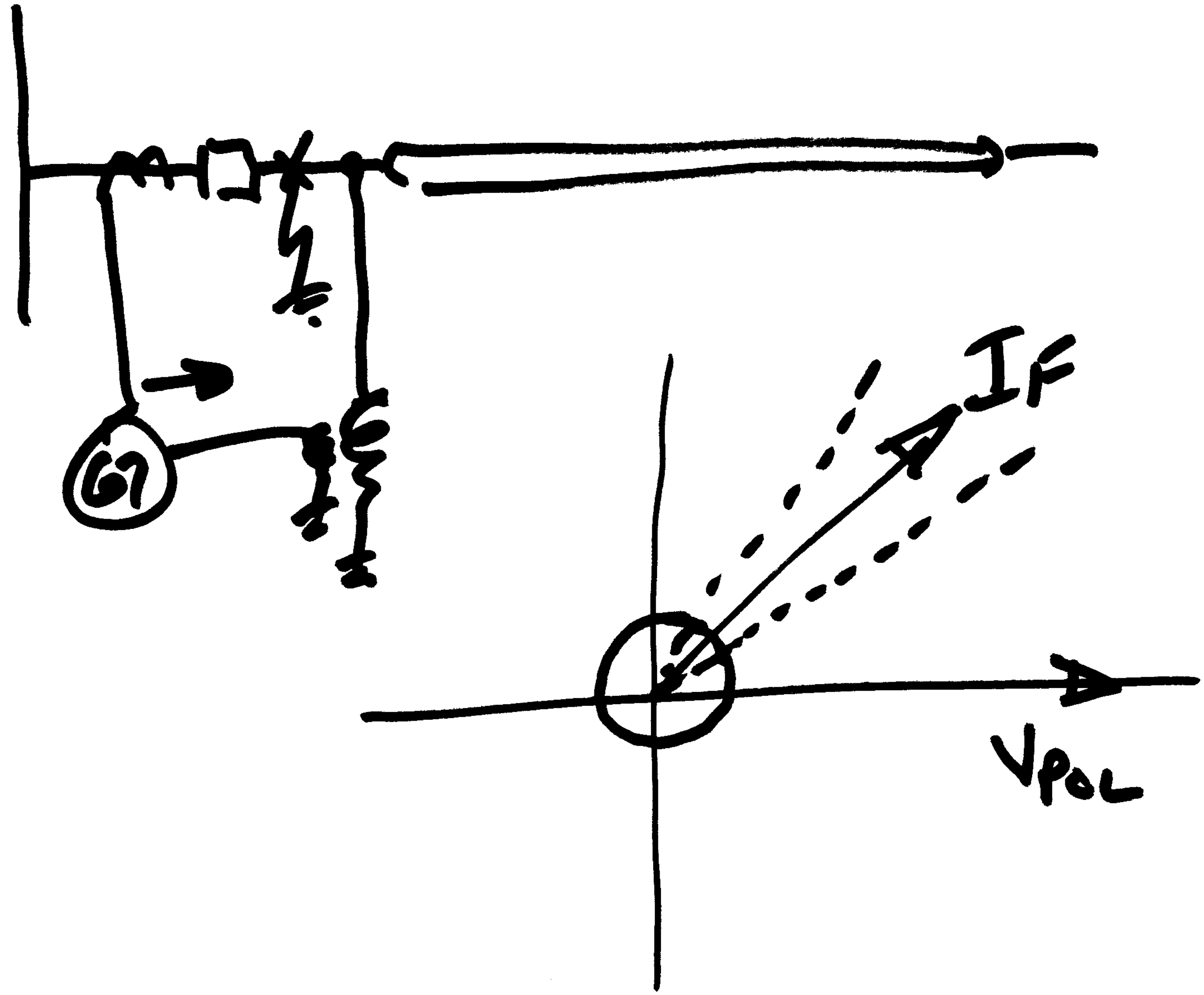
$$V_{AB} = V_{AG} - V_{BG}$$



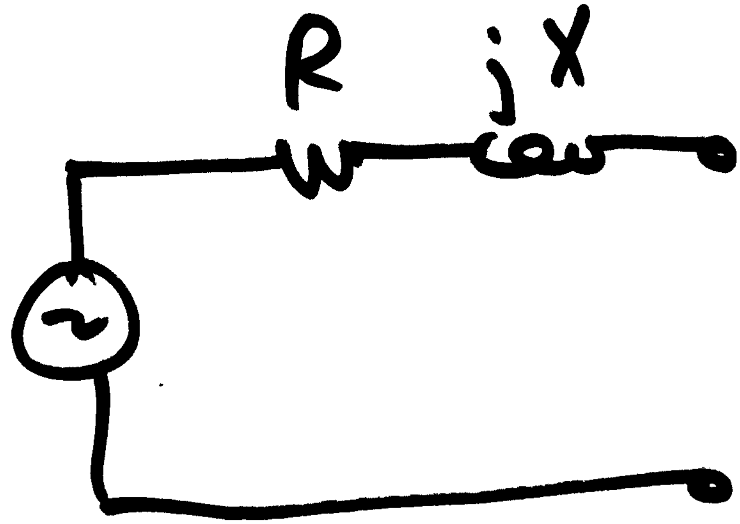
$$\frac{X}{R} = 1$$

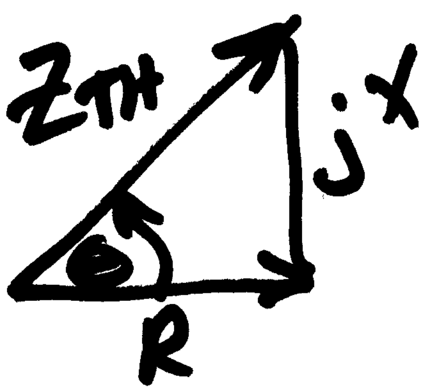
$$V_{A0} + V_{B0} + V_{C0} = 3V_0$$
$$= V_{AG} + V_{BG} + V_{CG}$$





IF
VPOL

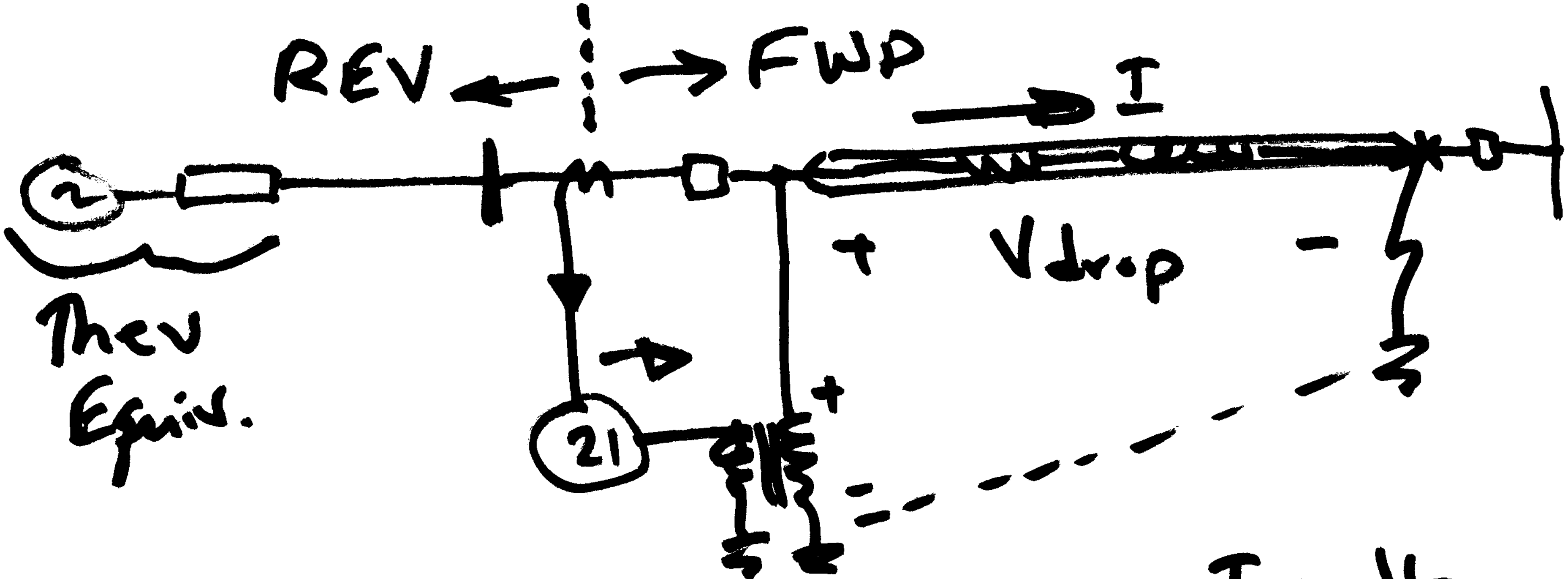




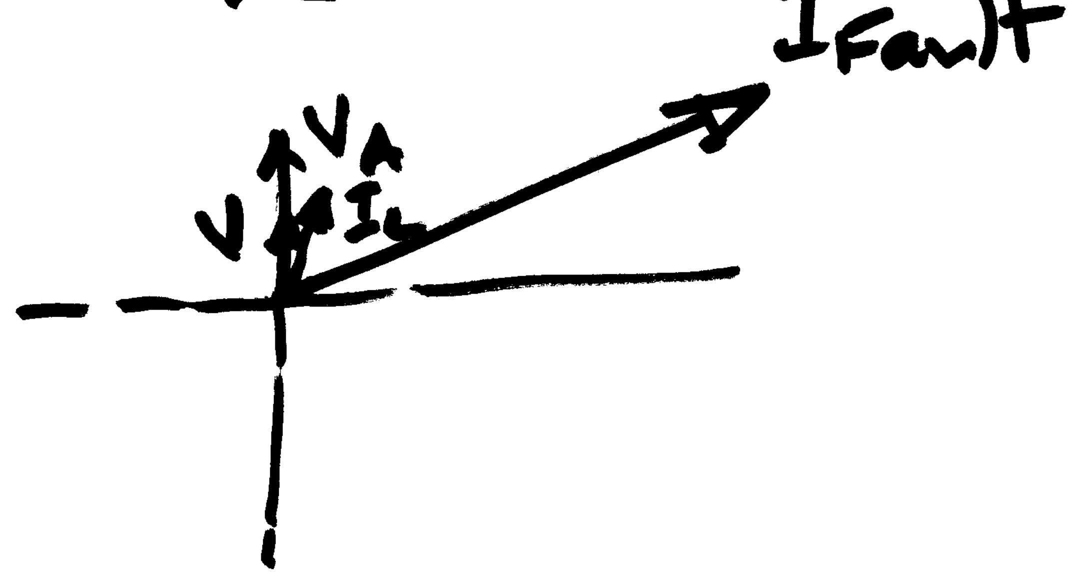
$\frac{X}{R} = 1 \Rightarrow \theta = 45°$

$\frac{X}{R} = 10 \Rightarrow \theta = 84.3°$

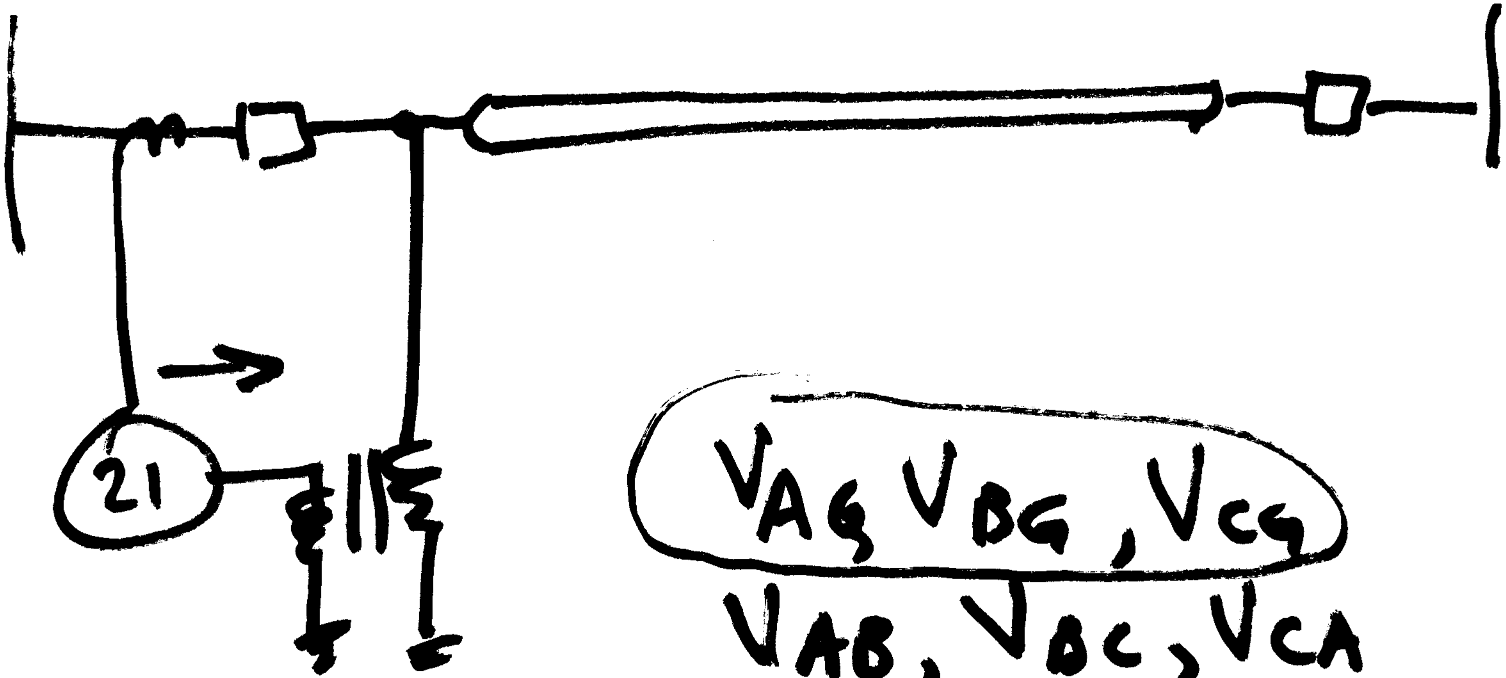
$\frac{X}{R} = \infty \Rightarrow \theta = 90°$



$$\bar{Z} = \frac{\tilde{V}}{\tilde{I}}$$



Pre-Fault (load)
⇒ Z is big, small angle
Fault
⇒ Z gets small, angle gets big (line imped angle)



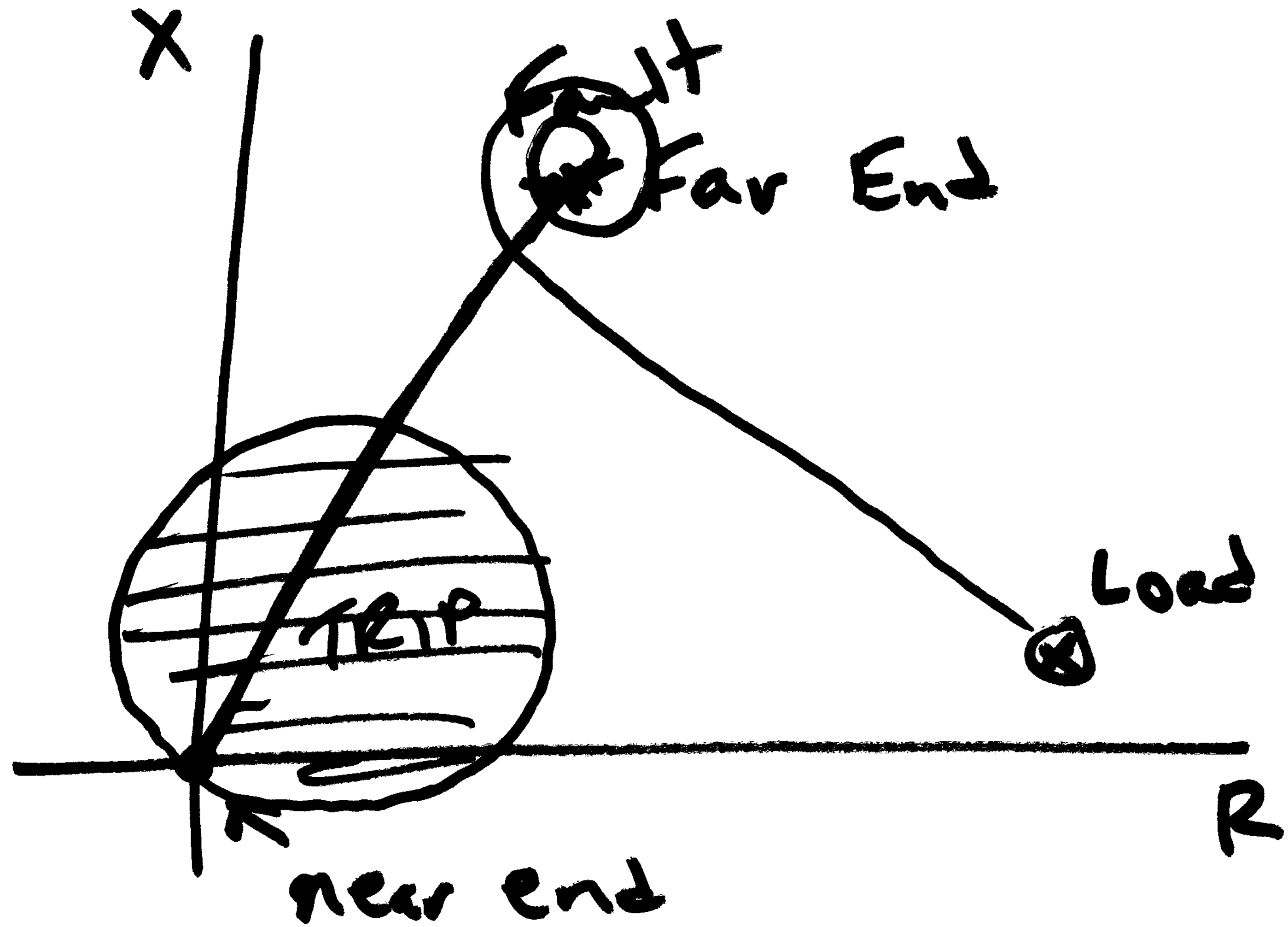
V_{AG} V_{BG}, V_{CG}

V_{AB}, V_{BC}, V_{CA}

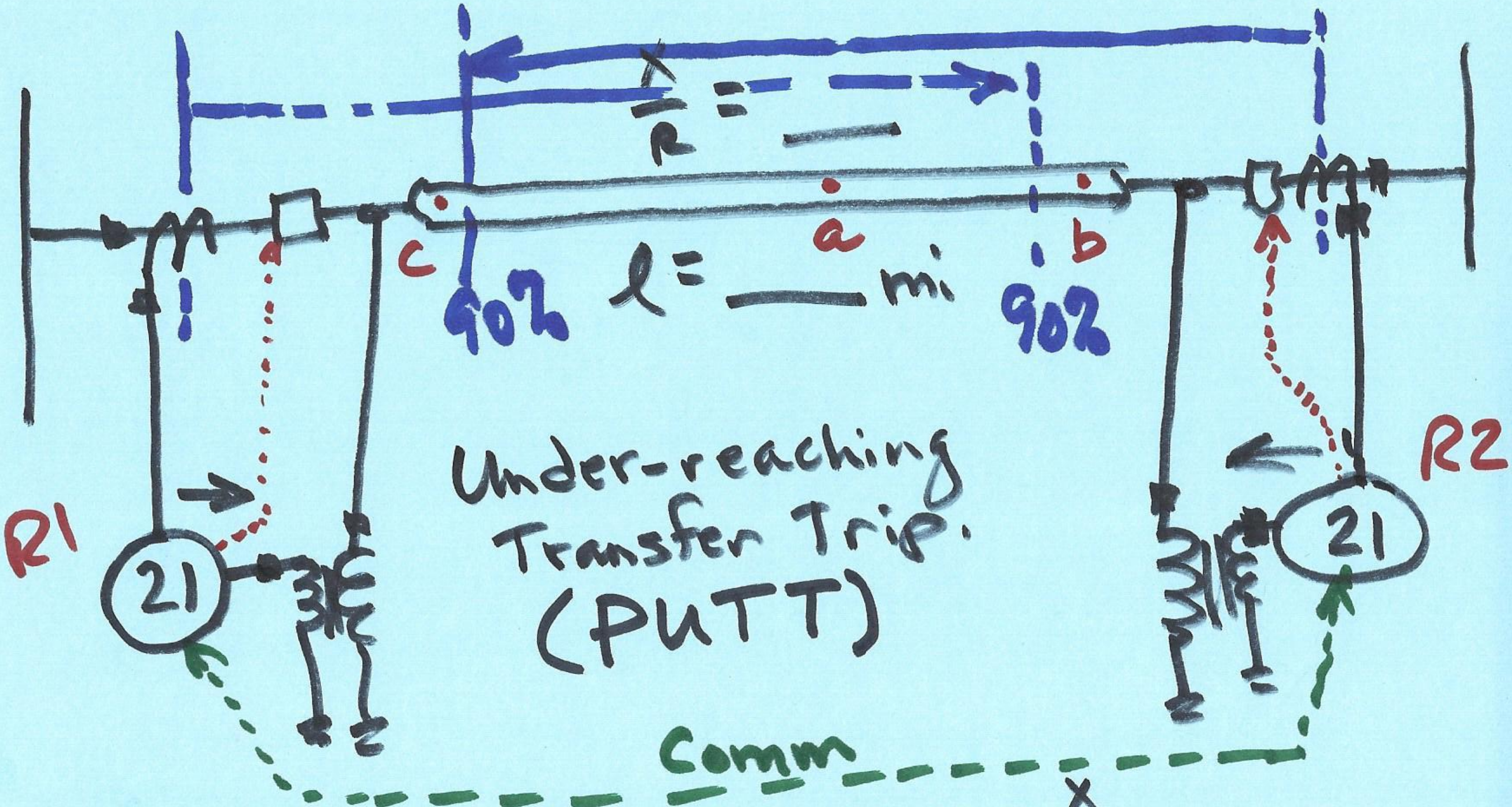
$$\overline{Z} = \frac{V_{Relay}}{I_{Relay}} \Rightarrow \frac{V_{A0},\ V_{A1},\ V_{A2}}{I_A,\ I_B,\ I_C}$$

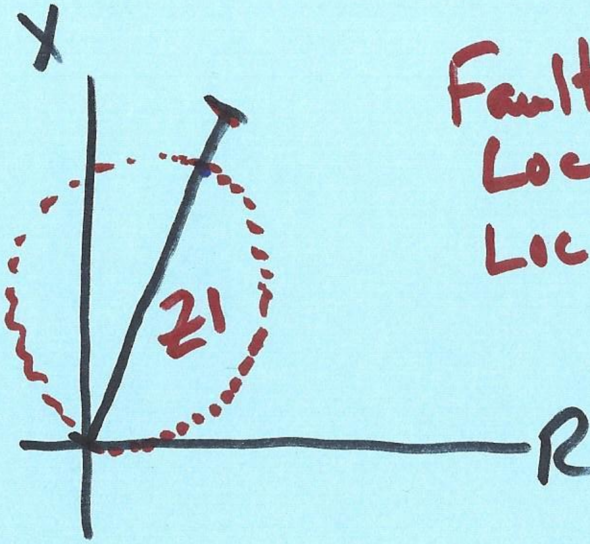
I_{A0}, I_{B0}, I_{C0}

"Delta Currents": $(I_A - I_B)$, $(I_B - I_C)$, $(I_C - I_A)$


X
Fault
Far End
Load
TRIP
R
near end

Under-reaching Transfer Trip (PUTT)



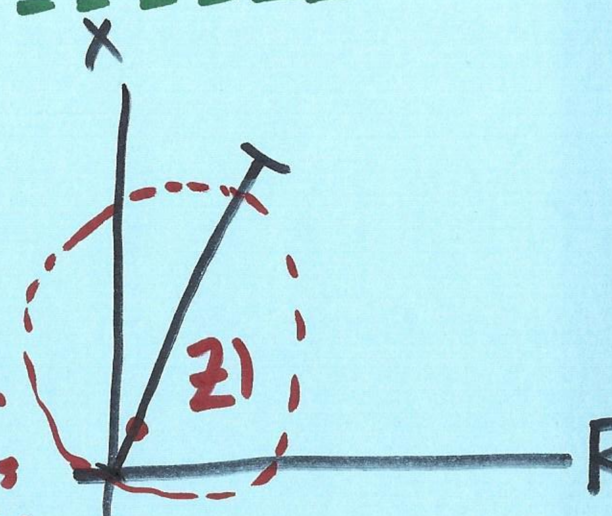


Fault:

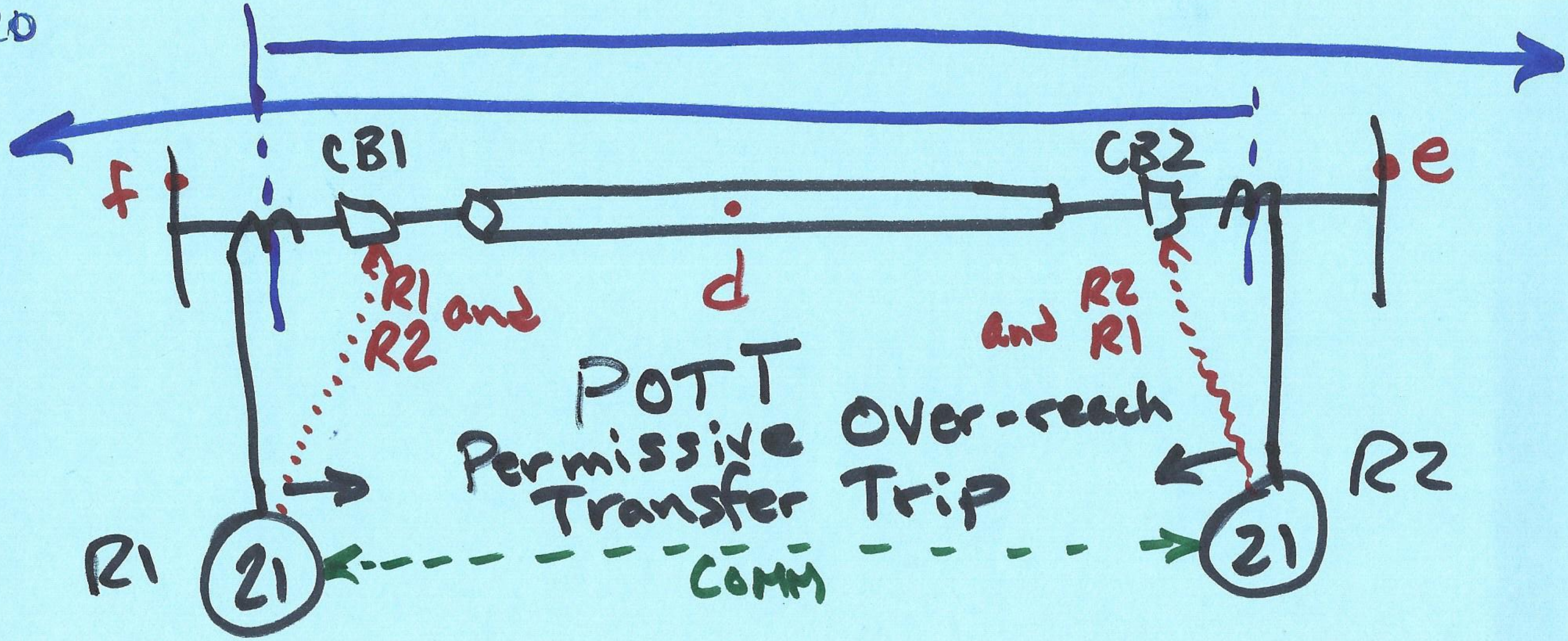
Loc a: Both trip

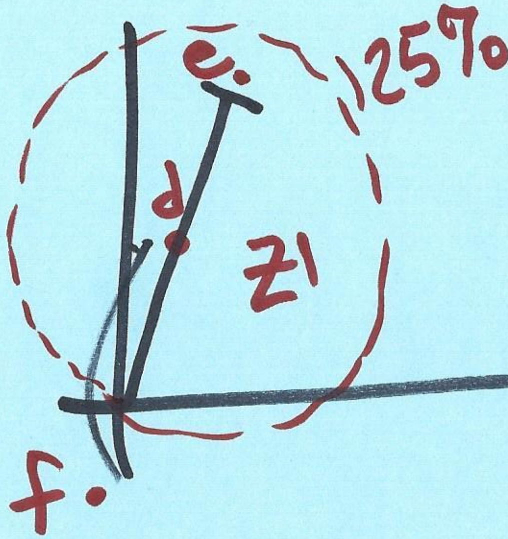
Loc b: R2 trips
R2 send TT
to other end.

Loc c: R1 trips
R1 sends
TT to R2.



L20





Case d:

CB1 trip: R1 and R2

CB2 trip: R2 and R1

Case e:

R1 + R2 = 0