EE 5223 - Lecture 25 Mon Mar 13, 2023

Ongoing List of Topics:

- URL: https://pages.mtu.edu/~bamork/EE5223/index.htm
- Term Project - all proj/teams are firmed up and moving.
  - Follow timeline, see posting on web page
  - Formal outline w/complete reference list due end of this week

- Protection fundamentals (cont'd):
  - Distance relaying fundamentals: §6.5.6, §6.5.7
  - Observed vs actual Z: Three-terminal lines, series caps
  - Again — overview of bus diff, xfmr diff, synch check, capacitor banks, generators, motors, etc. (take a quick run through Ch.6, also Glover & Sarma, Ch.10).

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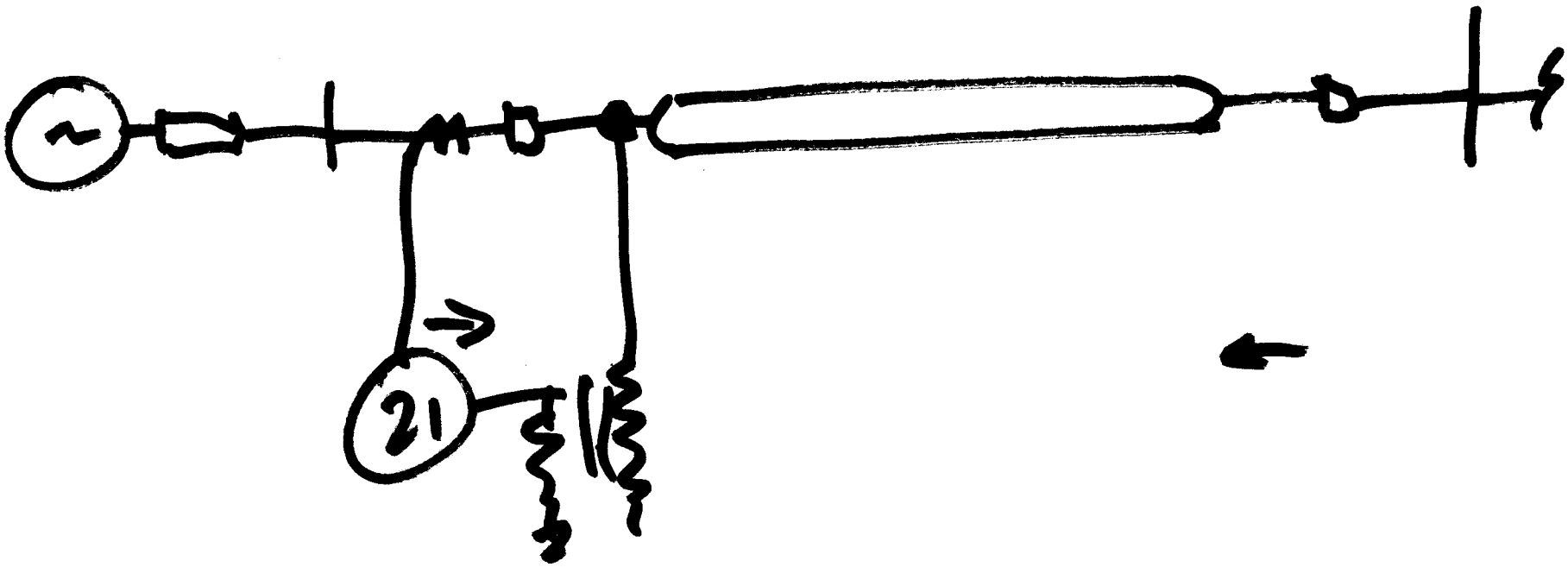
- Protection fundamentals in preparation for next EE5224 relaying lab:
  - Gen diff 87G - quite simple, connect CTs so current flows in “do-nothing” loop through Restraint elements (resulting in near-zero current through Operate element). Use equal (preferably full) ratio with all CTs. Differential slope of trip characteristic is rather flat compared to 87T below. Example shown of how not to connect CT secondaries.
  - Xfmr diff 87T - a) must connect CT secondaries to provide proper phase shift so that restraint currents flowing through restraint elements are in phase; b) relay settings are used to compensate for pri voltage ratio and CT ratios. CT accuracy problems can be a big concern due to having to use less than full CT ratio, and having Pri and Sec CTs with different accuracy levels. Differential slope of trip characteristic can be 10%, 15%, 25% to allow for mismatch (measurement error) due to CT accuracy problems.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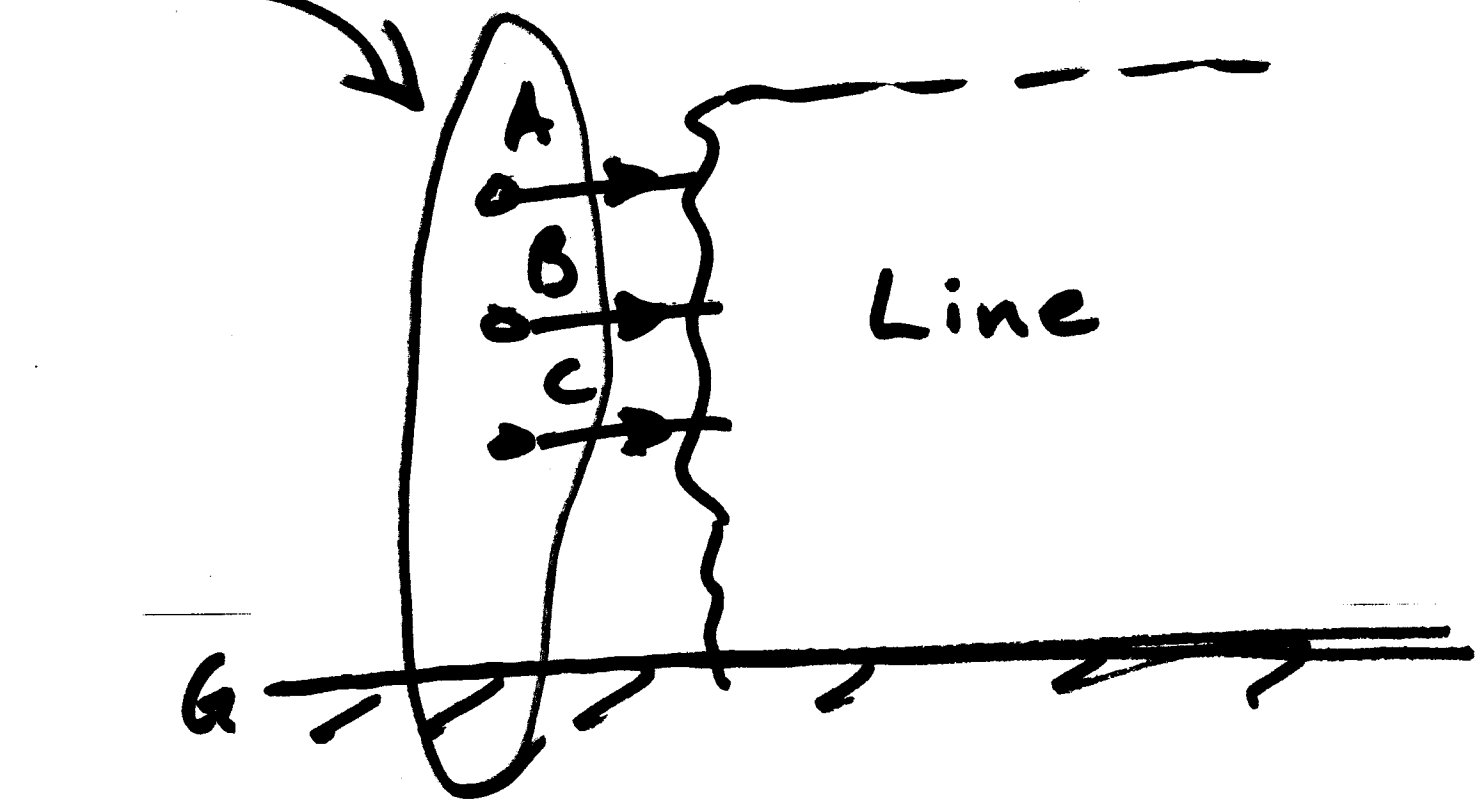
Relay "sees" $\tilde{V}_{AG}, \tilde{V}_{BG}, \tilde{V}_{CA}$
$\tilde{I}_A, \tilde{I}_B, \tilde{I}_C$



What Z's can be calculated?

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

$$\bar{Z}(\omega) = \frac{\tilde{V}(\omega)}{\tilde{I}(\omega)}$$

Phase Impedances:

$$\bar{Z}_A = \frac{\tilde{V}_{AG}}{\tilde{I}_A}$$

$$\bar{Z}_B = \frac{\tilde{V}_{BG}}{\tilde{I}_B}$$

$$\bar{Z}_C = \frac{\tilde{V}_{CG}}{\tilde{I}_C}$$

SEQ IMPEDANCES

$$\bar{Z}_0 = \frac{\tilde{V}_{A0}}{\tilde{I}_{A0}}$$

$$\bar{Z}_1 = \frac{\tilde{V}_{A1}}{\tilde{I}_{A1}}$$

$$\bar{Z}_2 = \frac{\tilde{V}_{A2}}{\tilde{I}_{A2}}$$

"DELTA IMPEDANCES"

$$\bar{Z}_{AB} = \frac{\tilde{V}_{AB}}{(\tilde{I}_A - I_B)}$$

$$\bar{Z}_{BC} = \frac{\tilde{V}_{BC}}{(\tilde{I}_A - \tilde{I}_B)}$$

$$\bar{Z}_{CA} = \frac{\tilde{V}_{CA}}{(\tilde{I}_C - \tilde{I}_A)}$$

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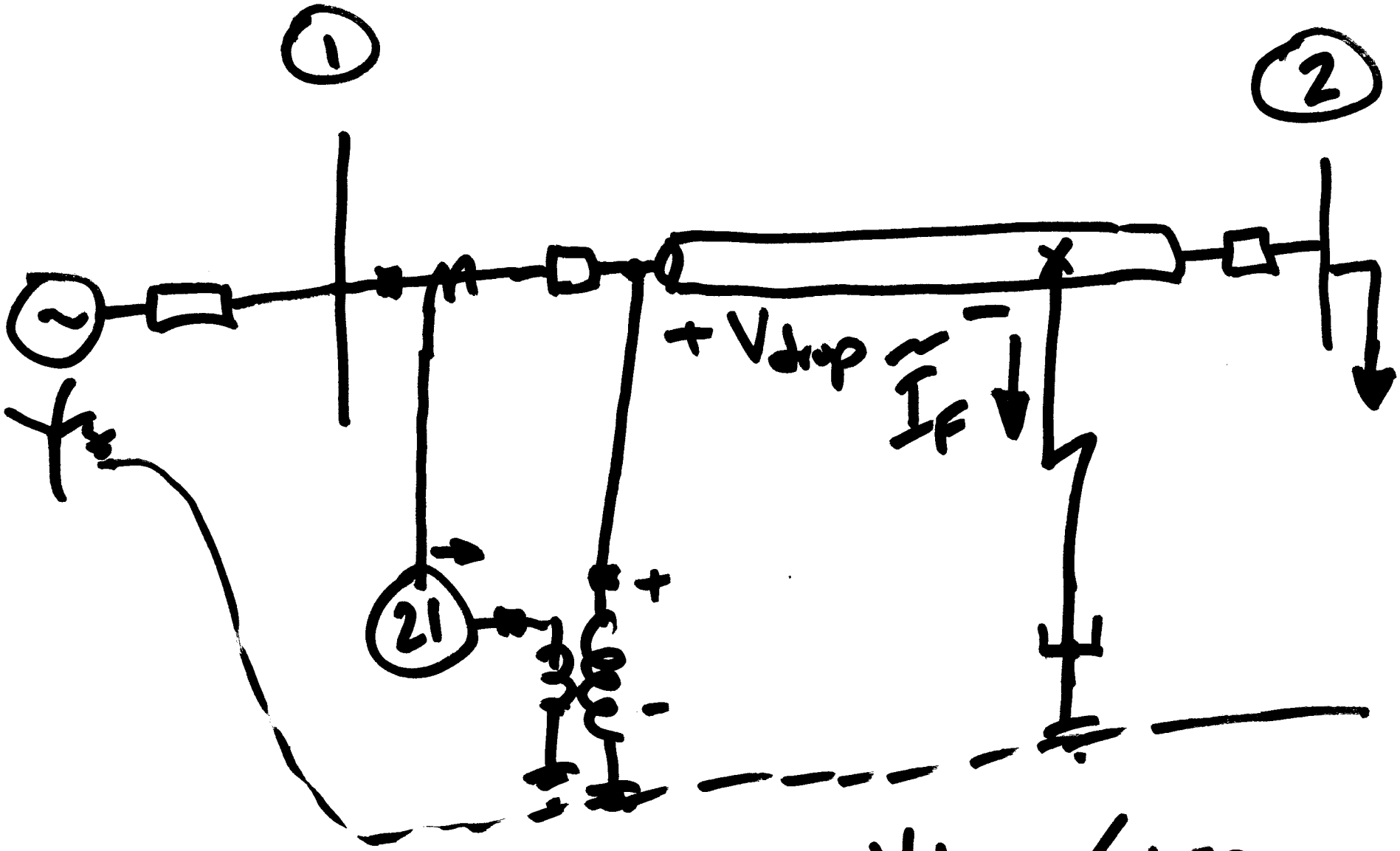
→ "Literature"

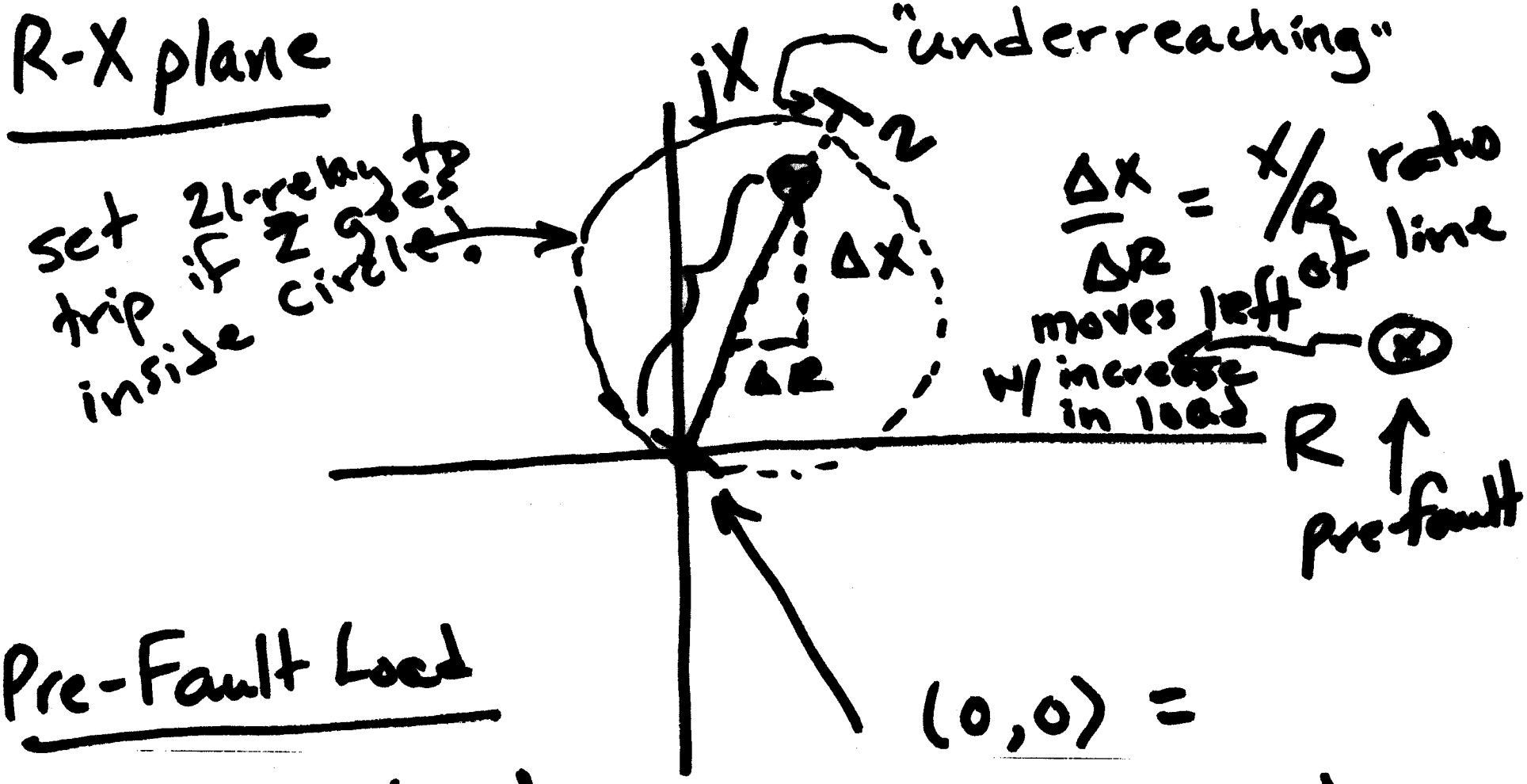
→ Impedance Meas.

"Incremental Impedances"



$$\bar{Z}_{RLY} = \frac{V_{drop} / VTR}{I_{LINE} / CTR}$$

R-X plane



Pre-Fault Load

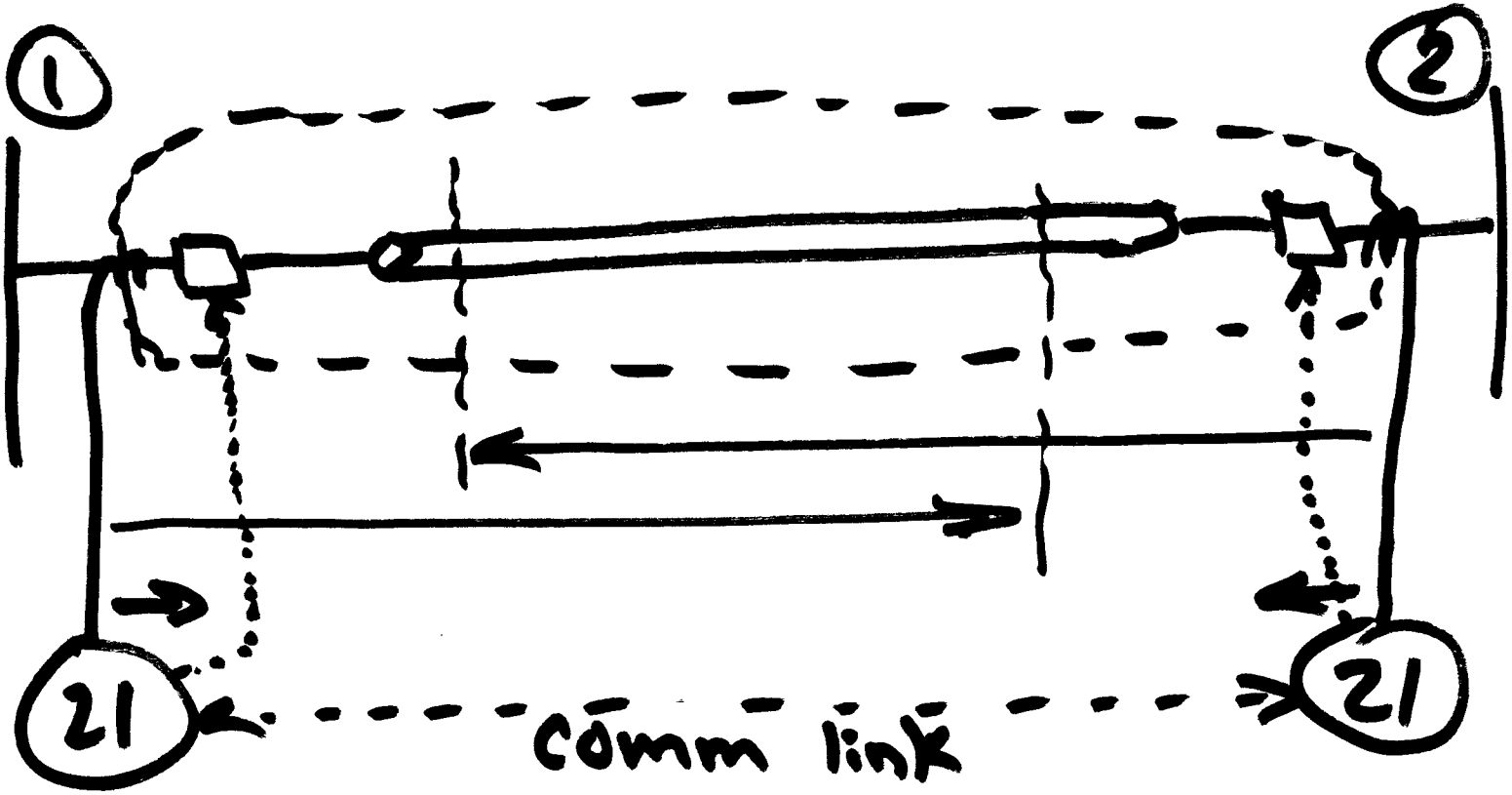
$\tilde{V}_{BUS}$

$\tilde{I}_{Load}$

ϕ

$\Theta = -\phi$

$\tilde{I}_{Load} = \frac{\tilde{V}_{SW}}{Z_{PRE}}$



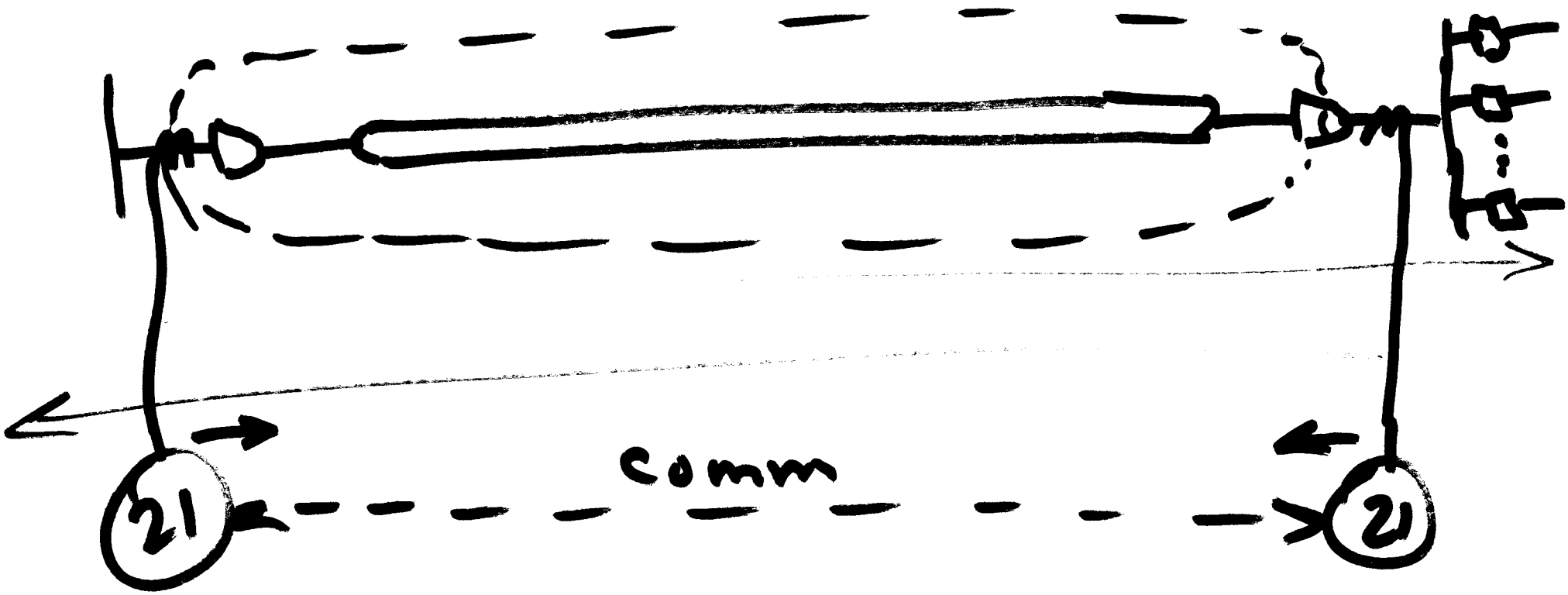
21@ Bus 1 trips, TT→ Bus 2

Both relays trips

21@ Bus 2 Trips, TT→ Bus 1

"Pilot Relaying"

PUTT

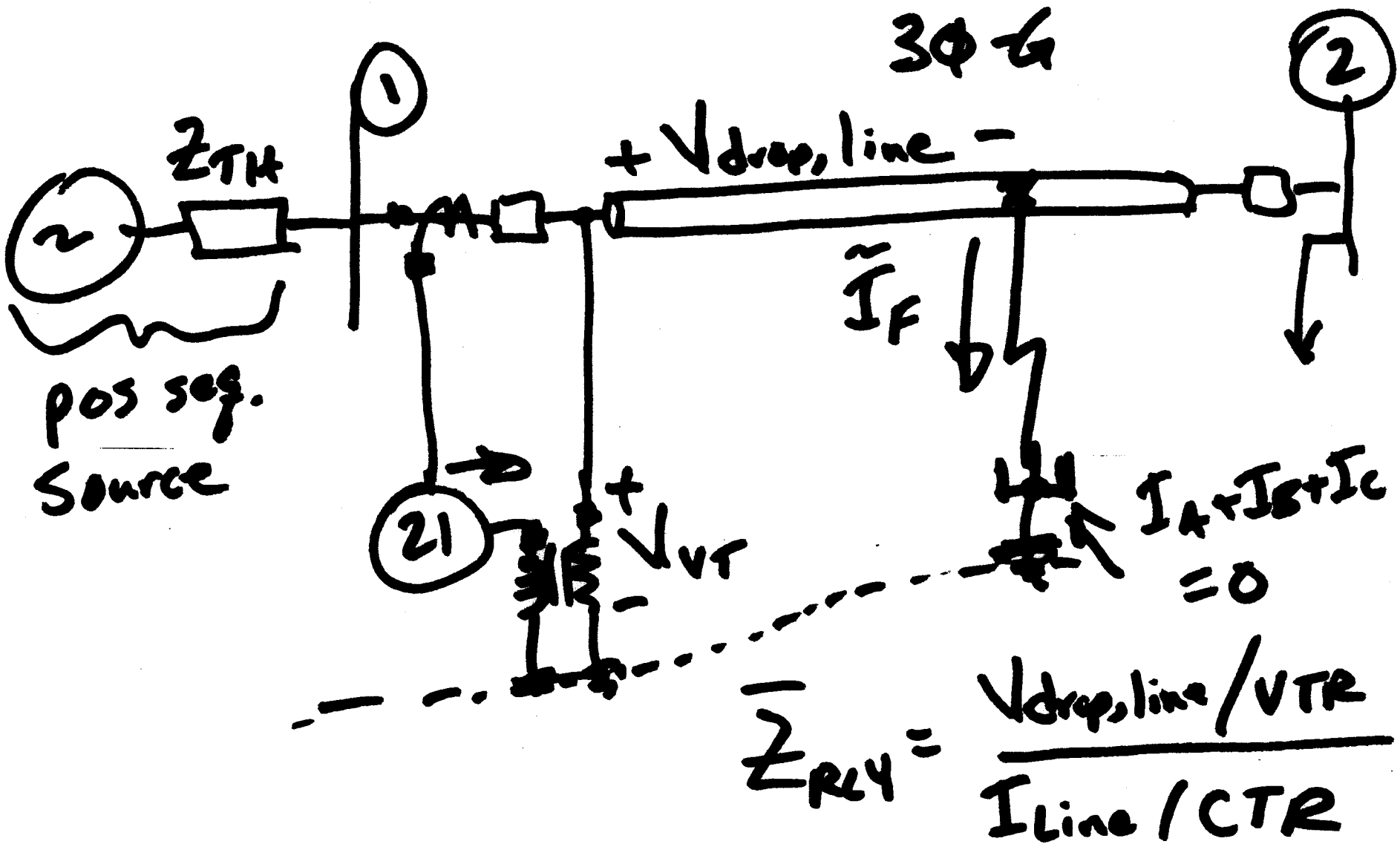


Trip CB's if both relays see fault in fwd direction.

POTT

Impedance Relaying – (21)

"distance relaying"



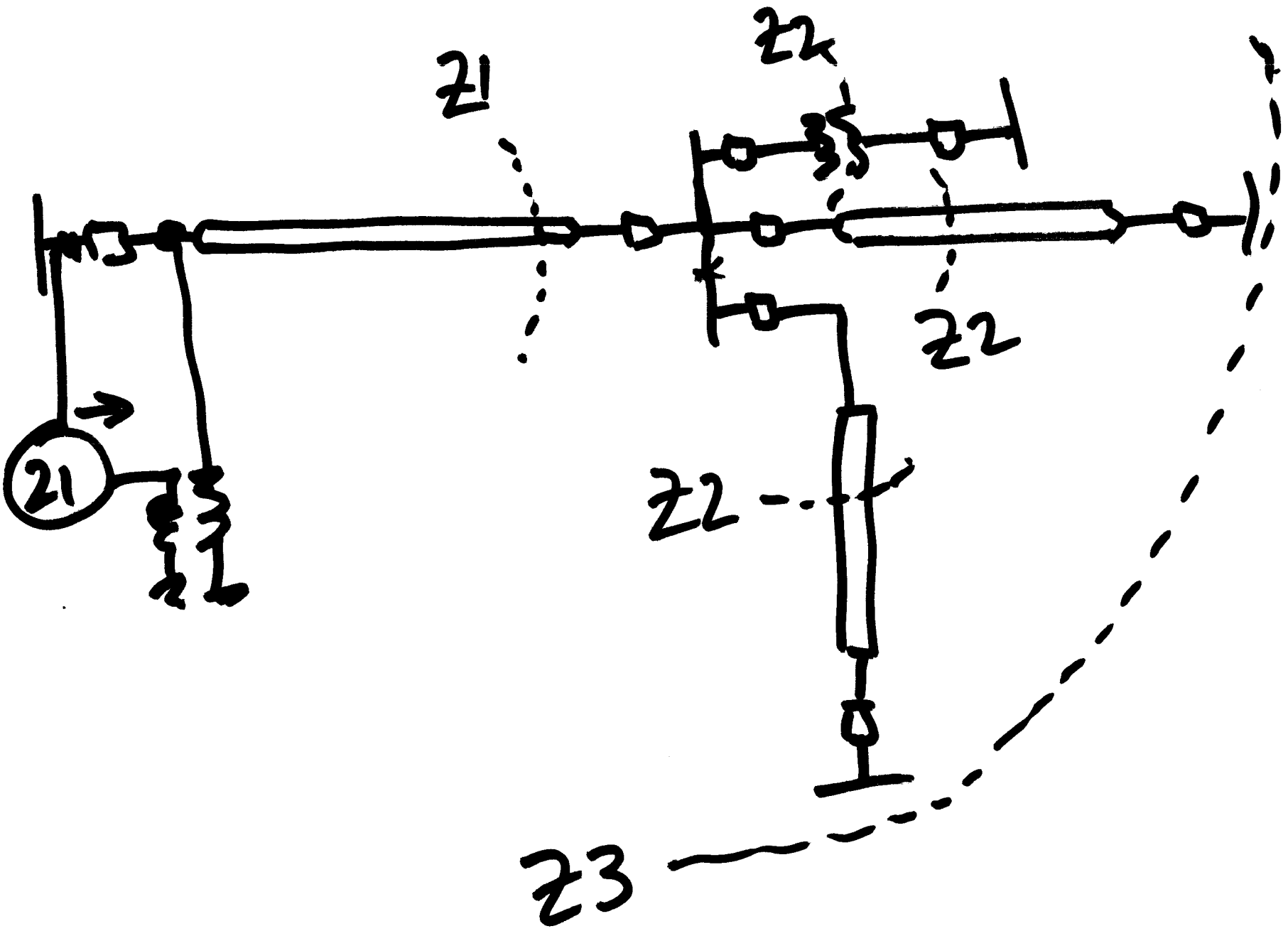

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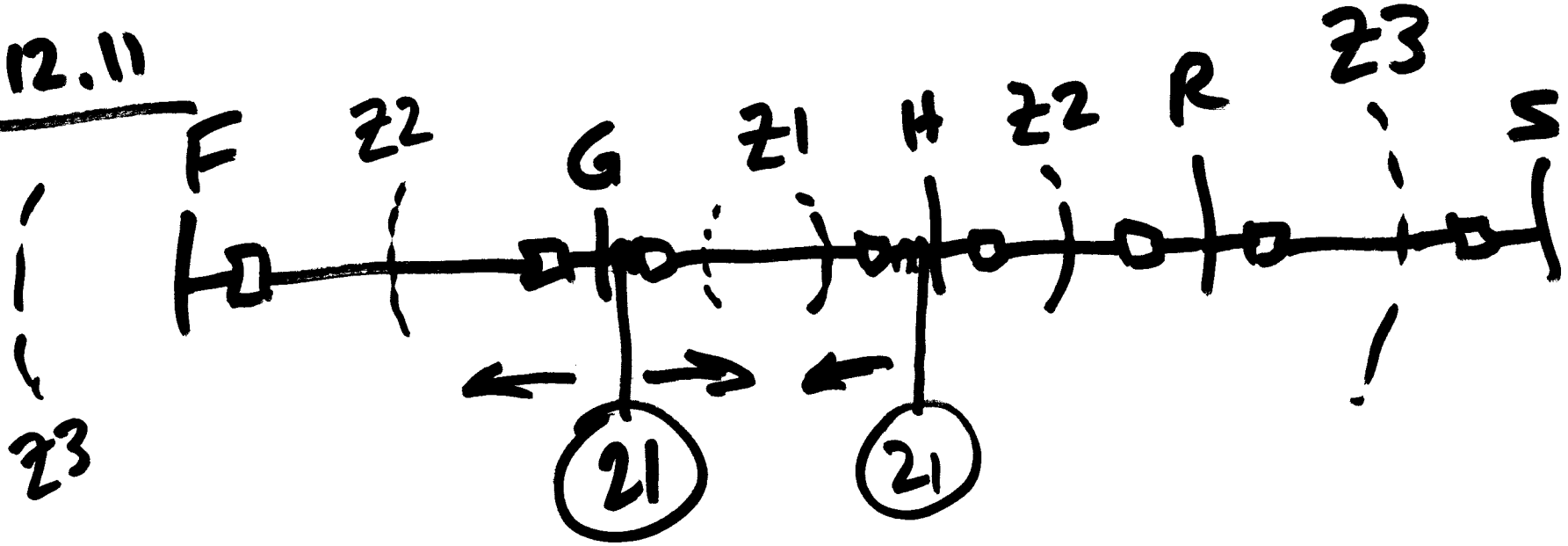
Fig 12.11



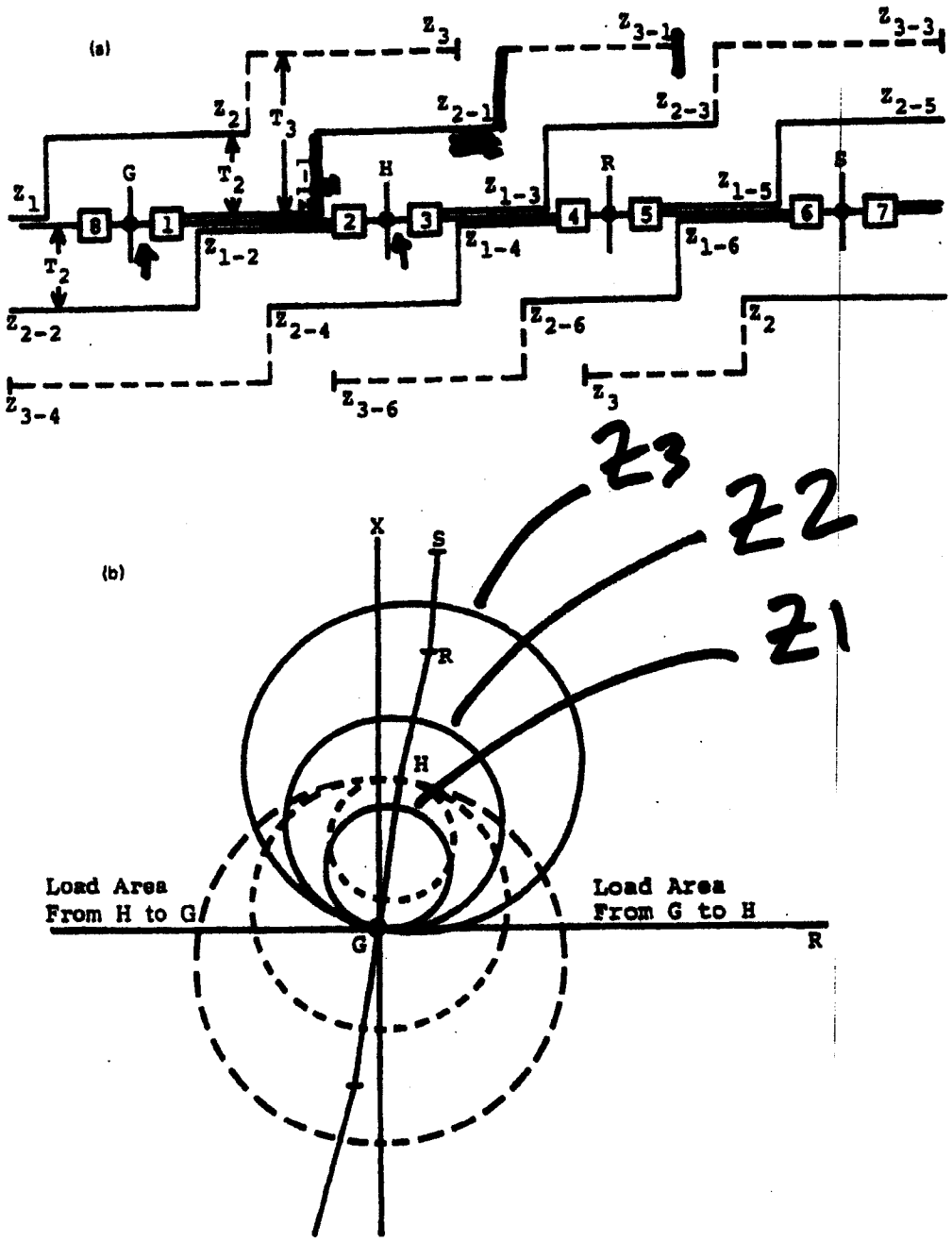


FIGURE 12.11 Protection zones with distance relays: (a) time–distance plot; (b) *R–X* diagram plot.

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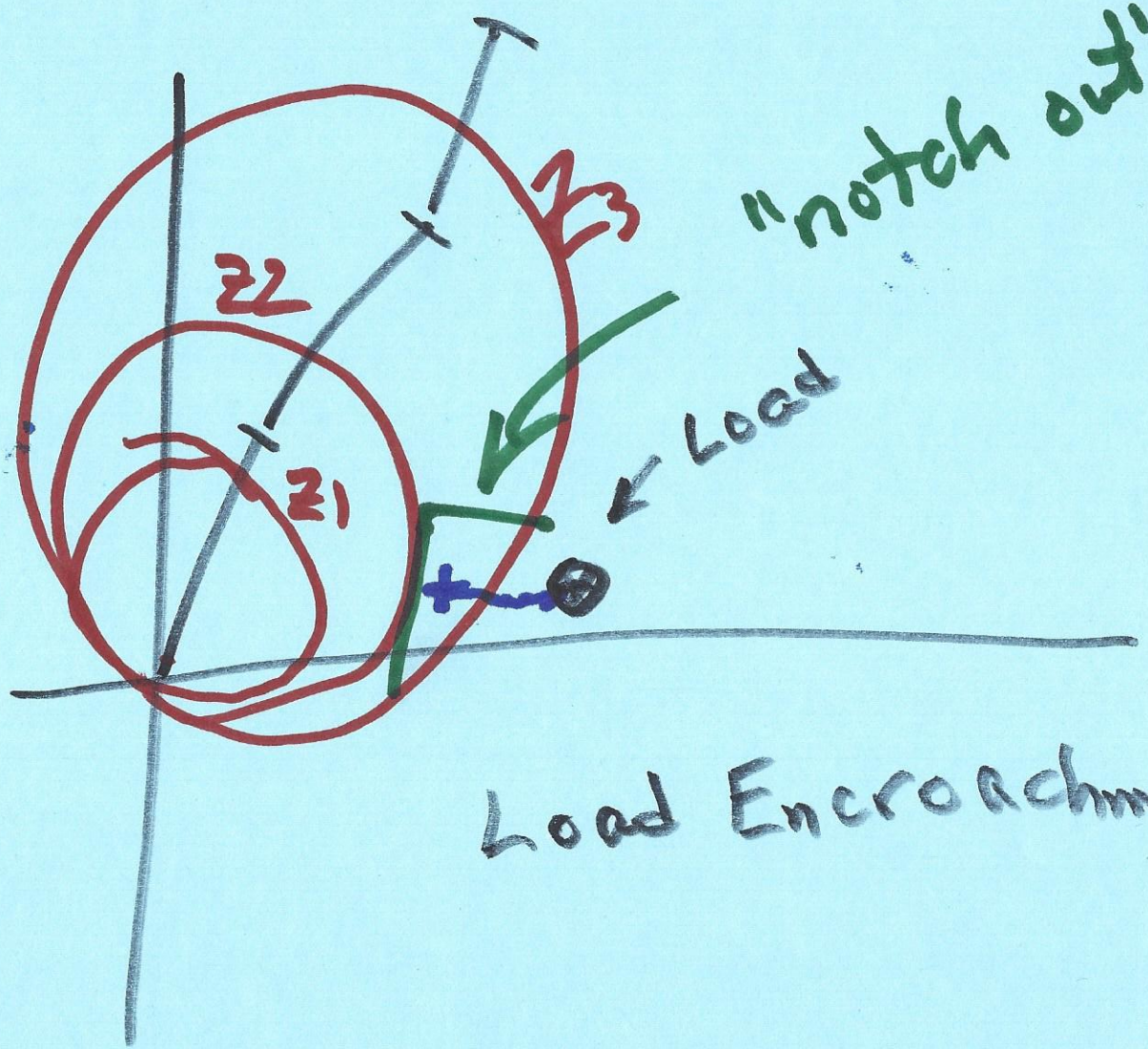
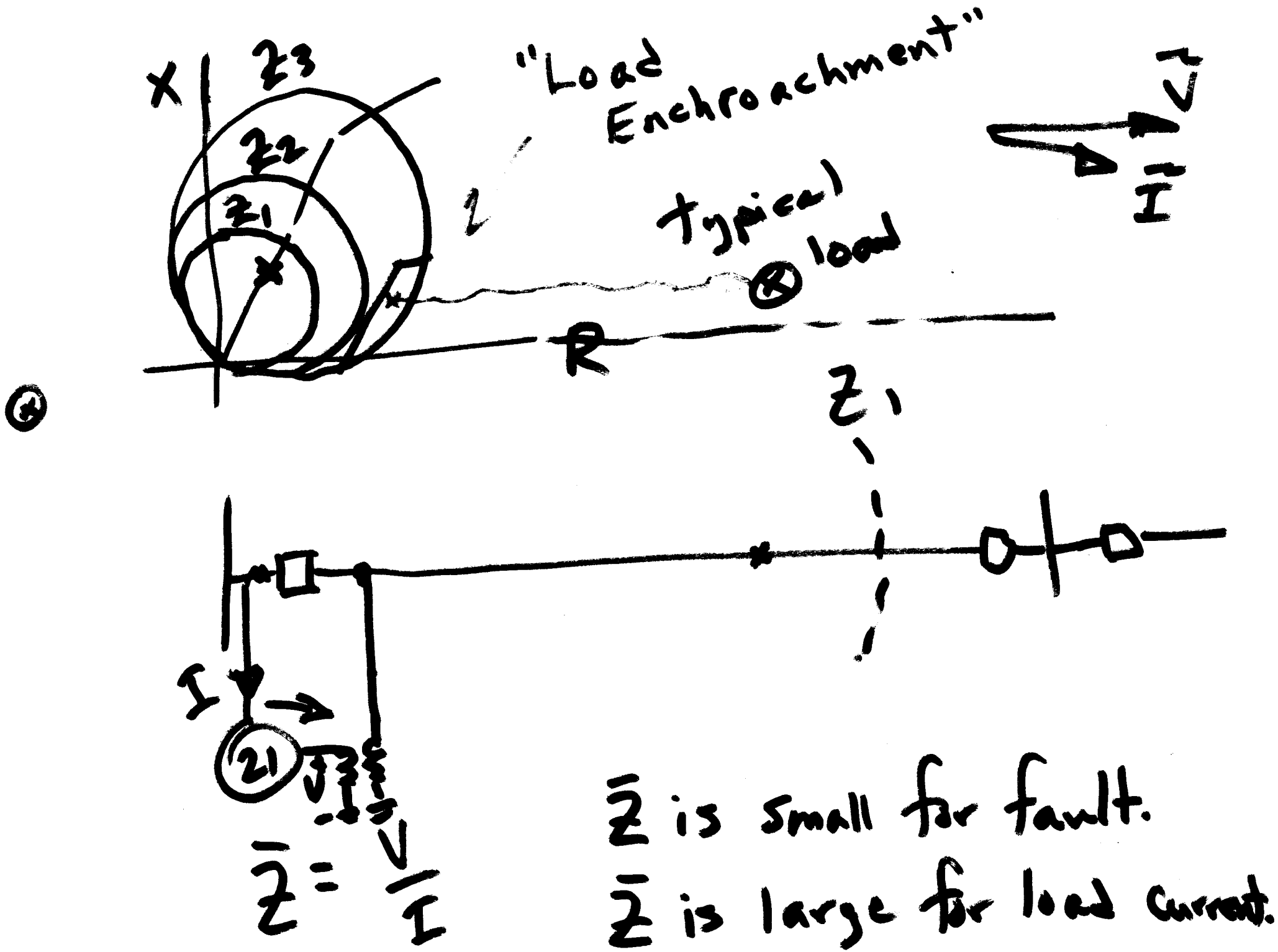


Load Encroachment


X
Z3
Z2
Z1
"Load Enchroachment"
typical load
R
V
I
Z1
I
21
$\bar{Z} = \frac{V}{I}$
$\bar{Z}$ is small for fault.
$\bar{Z}$ is large for load current.