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ECE 525

POWER SYSTEM PROTECTION AND RELAYING

SESSION no. 17

Zhm at 100MV
ZhL at 20MVA
ZmL at 20MVA

Calculating Z_h, Z_m and Z_l

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Lecture 16

- Often given short circuit test data as Z_{hm}, Z_{hl} and Z_{ml}
- Not all on same per unit base, so first do change of base

source on h, short L with m open

$$X_h := \left(\frac{1}{2}\right)\cdot\left(X_{hl} + X_{hm} - X_{ml}\right)$$

$$X_m := \left(\frac{1}{2}\right)\cdot\left(X_{hm} + X_{ml} - X_{hl}\right)$$

$$X_l := \left(\frac{1}{2}\right)\cdot\left(X_{ml} + X_{hl} - X_{hm}\right)$$

Component Modeling: Lines

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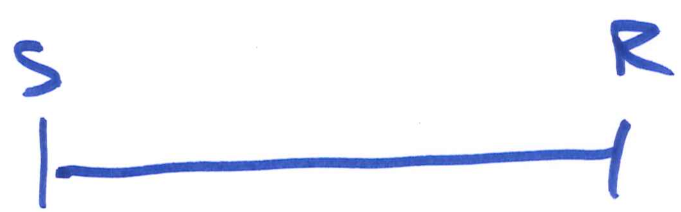
Lecture 16

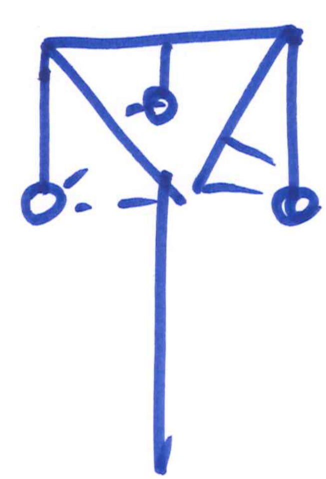
- Z_1=Z_2 -phase rotation doesn't impact
- Often approximated with per phase equivalent self impedance
- Zero sequence current flows through earth and Z_0 often 2-6 times Z_1
- Usually neglect capacitances unless transient case
  - » Transient response matters for fast detection

$$Z_{012} = \begin{bmatrix} Z_0 & Z_{01} & Z_{02} \\ Z_{10} & Z_1 & Z_{12} \\ Z_{20} & Z_{21} & Z_2 \end{bmatrix}$$

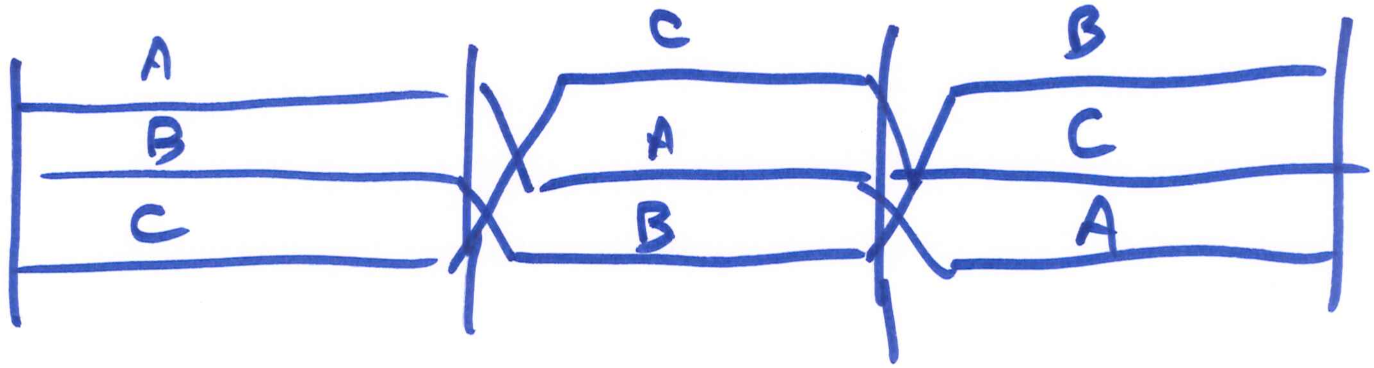
- off diagonal small
- approximation to neglect them

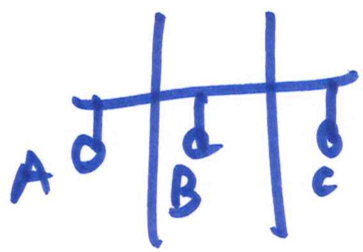
If line untransposed (and not an equilateral triangle space)

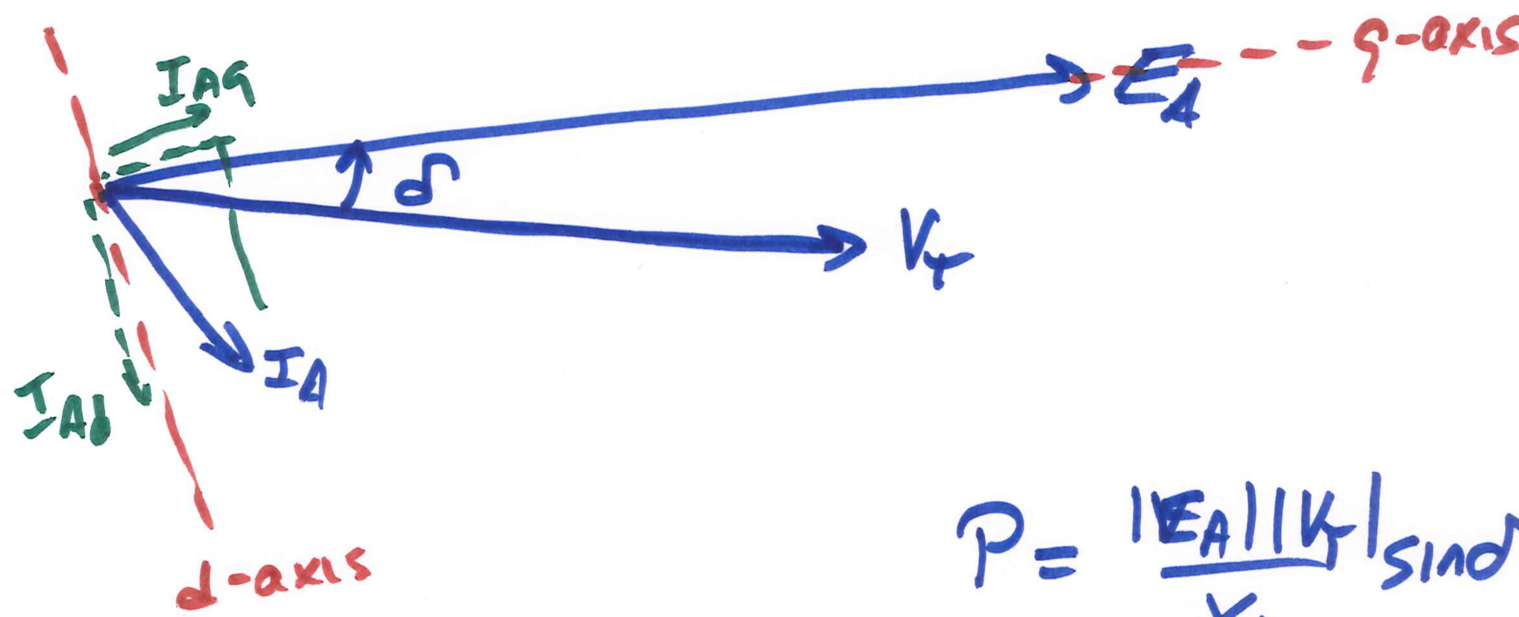




Transposed line?







$$P = \frac{|E_A||V_\phi|}{X_d} \sin\delta$$

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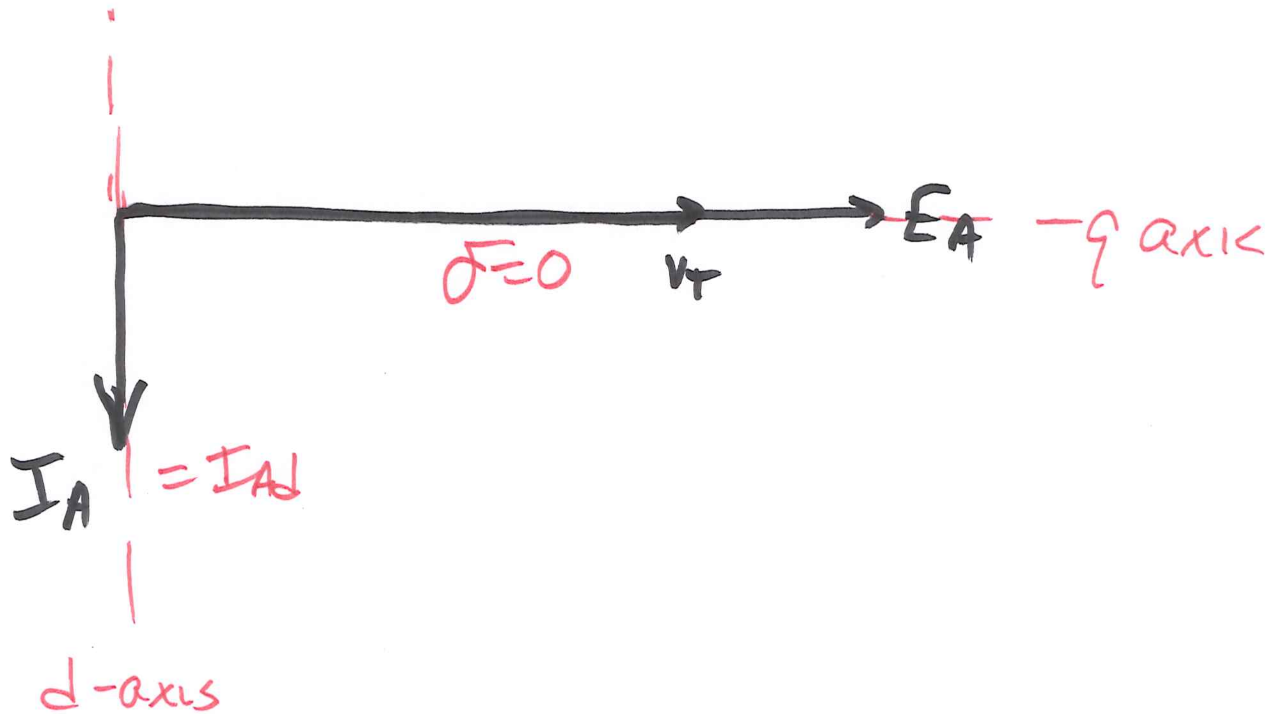
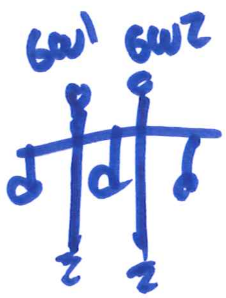
$P = 0$



Component Modeling: Lines

- Need to do detailed line constants calculation to get impedances accurately
- Form impedance matrix and then transform with Symmetrical Components Transformation matrix $Z_s=(A^{-1} * Z * A)$



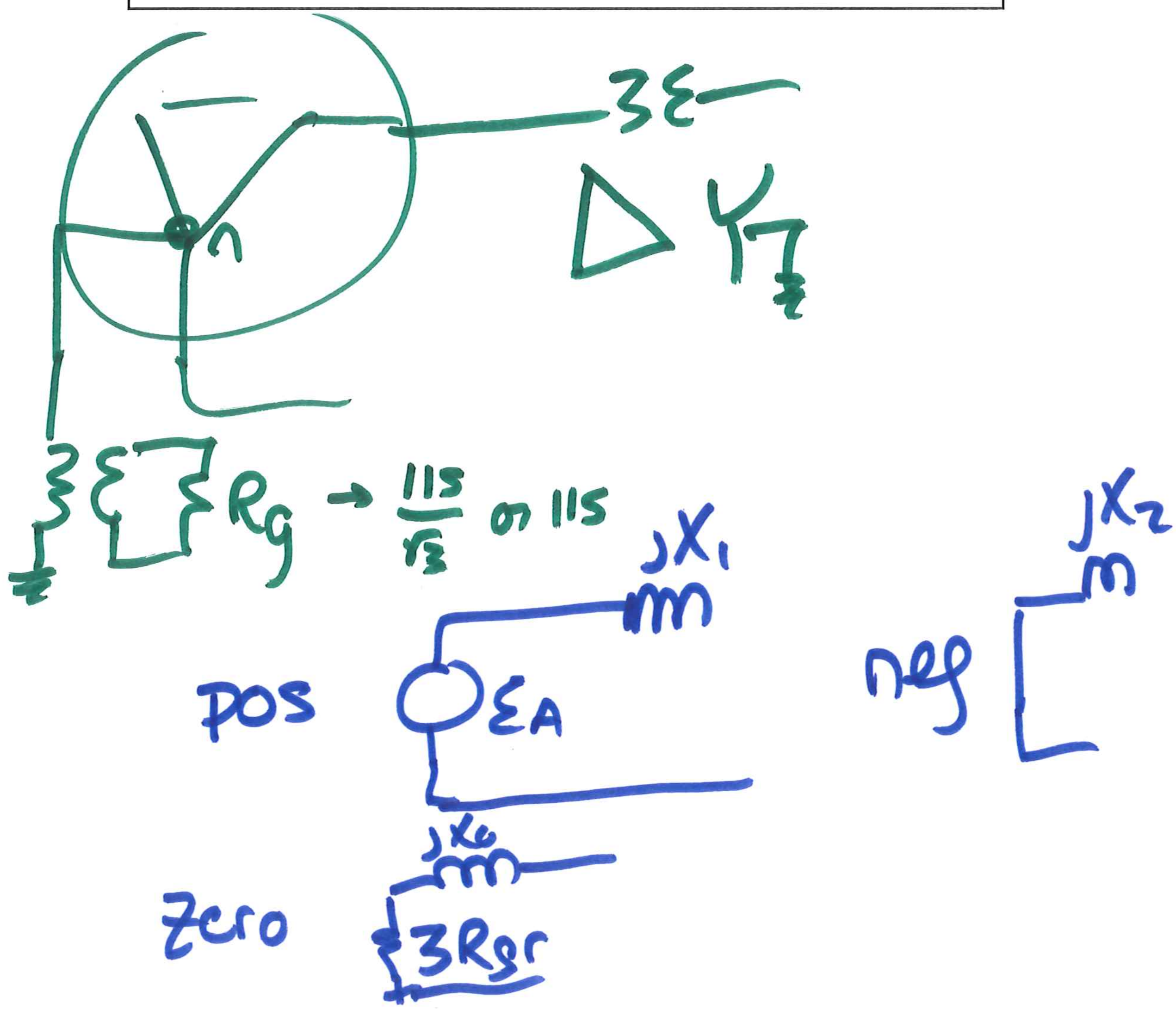
$$Z_{ABC} = \begin{bmatrix} Z_{AA} & Z_{AB} & Z_{AC} \\ Z_{BA} & Z_{BB} & Z_{BC} \\ Z_{CA} & Z_{CB} & Z_{CC} \end{bmatrix}$$

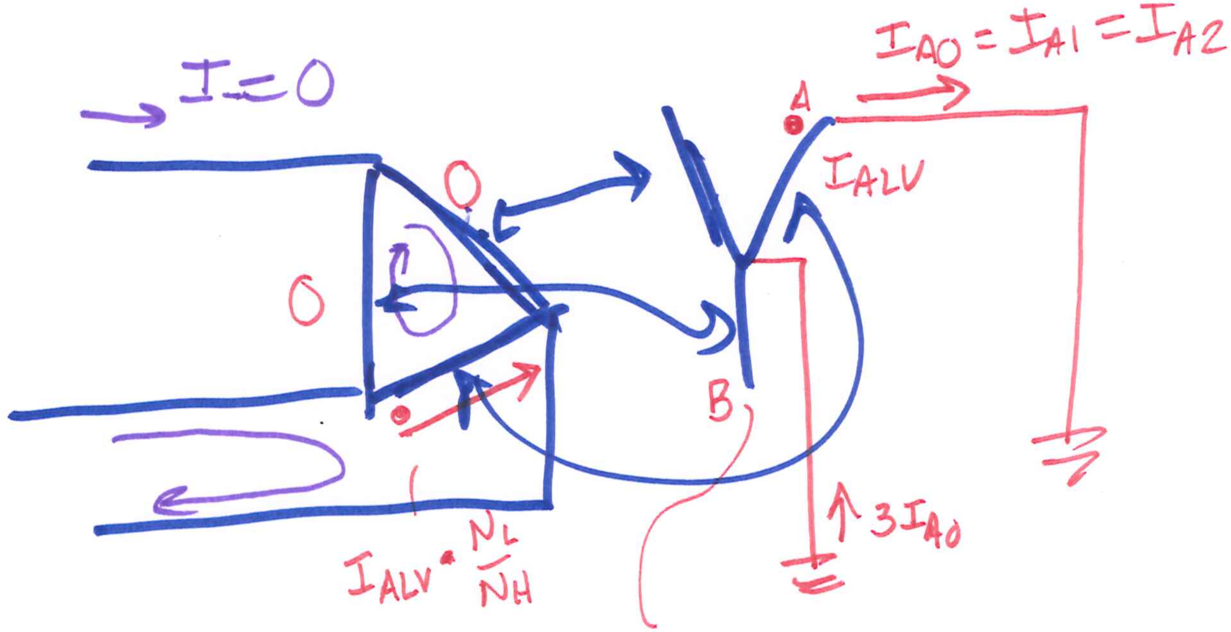
Generators

- Positive sequence reactance broken into subtransient, transient and steady-state
- Direct vs Quadrature axis
  - » Fault currents typically near zero power factor
  - » D-axis only
- Subtransient or transient reactance based on time scale of interest

Generators: Negative Sequence

- MMF rotates backwards at twice the machines synchronous speed
- Double frequency currents in the rotor field and amortisseur windings
- Flux peak occurs along the d and q - axes
- $X_2 \approx 0.5*(X_d" + X_q")$





$$I_{B0} + I_{B1} + I_{B2}$$

$$I_{A0} + a^2 I_{A1} + a I_{A2} = I_{A0}(1 + a^2 + a) = 0$$

Now move the currents from the low side to the high side (note, you must transform the sequence currents):

$$I_{1\_LLH} := I_{1\_LLf} \cdot e^{j \cdot 30deg} \qquad I_{0\_LLH} := 0pu$$

$$I_{2\_LLH} := I_{2\_LLf} \cdot e^{-j \cdot 30deg}$$

$$I_{abc\_LLh} := A_{012} \cdot \begin{pmatrix} I_{0\_LLH} \\ I_{1\_LLH} \\ I_{2\_LLH} \end{pmatrix} \qquad \left|\overrightarrow{I_{abc\_LLh}}\right| = \begin{pmatrix} 2.027 \\ 4.0541 \\ 2.027 \end{pmatrix} \cdot pu$$

- negative sequence overcurrent won't have this problem

$$\overrightarrow{\arg(I_{abc\_LLh})} = \begin{pmatrix} 0 \\ 180 \\ 0 \end{pmatrix} \cdot deg$$

Phase B per unit current is larger on the high side of the transformer than on the low side, use caution with coordination

Voltage at the fault point:

$$V_{1\_LL} := V_{src} - j \cdot X_1 \cdot I_{1\_LLf} \qquad |V_{1\_LL}| = 0.5 \cdot pu \qquad \arg(V_{1\_LL}) = 0 \cdot deg$$

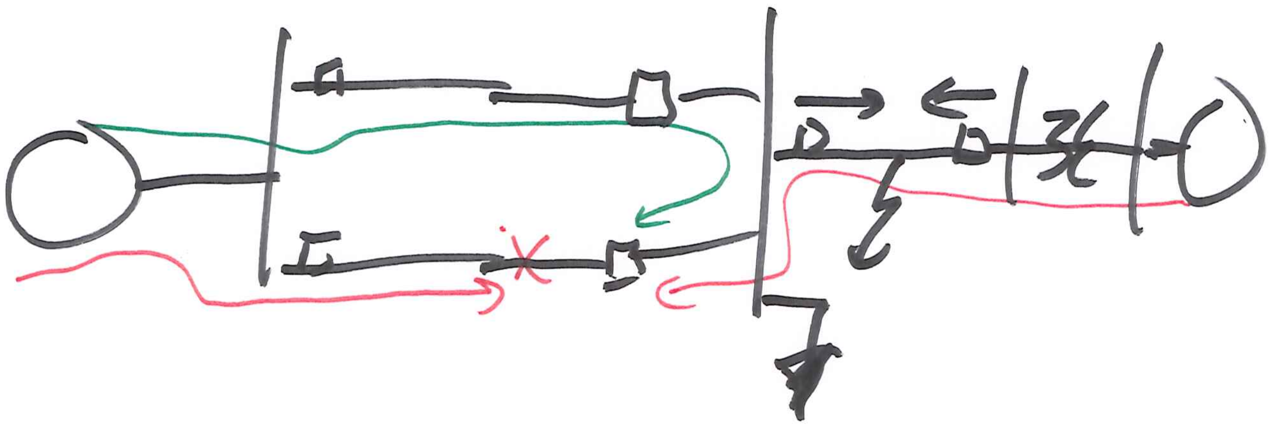
$$V_{2\_LL} := 0 - j \cdot X_2 \cdot I_{2\_LLf} \qquad |V_{2\_LL}| = 0.5 \cdot pu \qquad \arg(V_{2\_LL}) = 0 \cdot deg$$

$$V_{0\_LL} := 0 - j \cdot X_0 \cdot I_{0\_LLf} \qquad |V_{0\_LL}| = 0 \cdot pu$$

$$V_{abc\_LL} := A_{012} \cdot \begin{pmatrix} V_{0\_LL} \\ V_{1\_LL} \\ V_{2\_LL} \end{pmatrix} \qquad \left|\overrightarrow{V_{abc\_LL}}\right| = \begin{pmatrix} 1 \\ 0.5 \\ 0.5 \end{pmatrix} \cdot pu$$

www.powerworld.com/gloversarmaoverbye

Directional Determination



- Directional supervision protection elements to minize amount of system tripped
- improve selectivity

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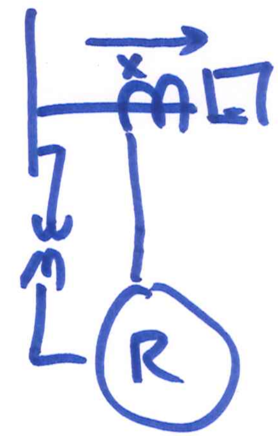
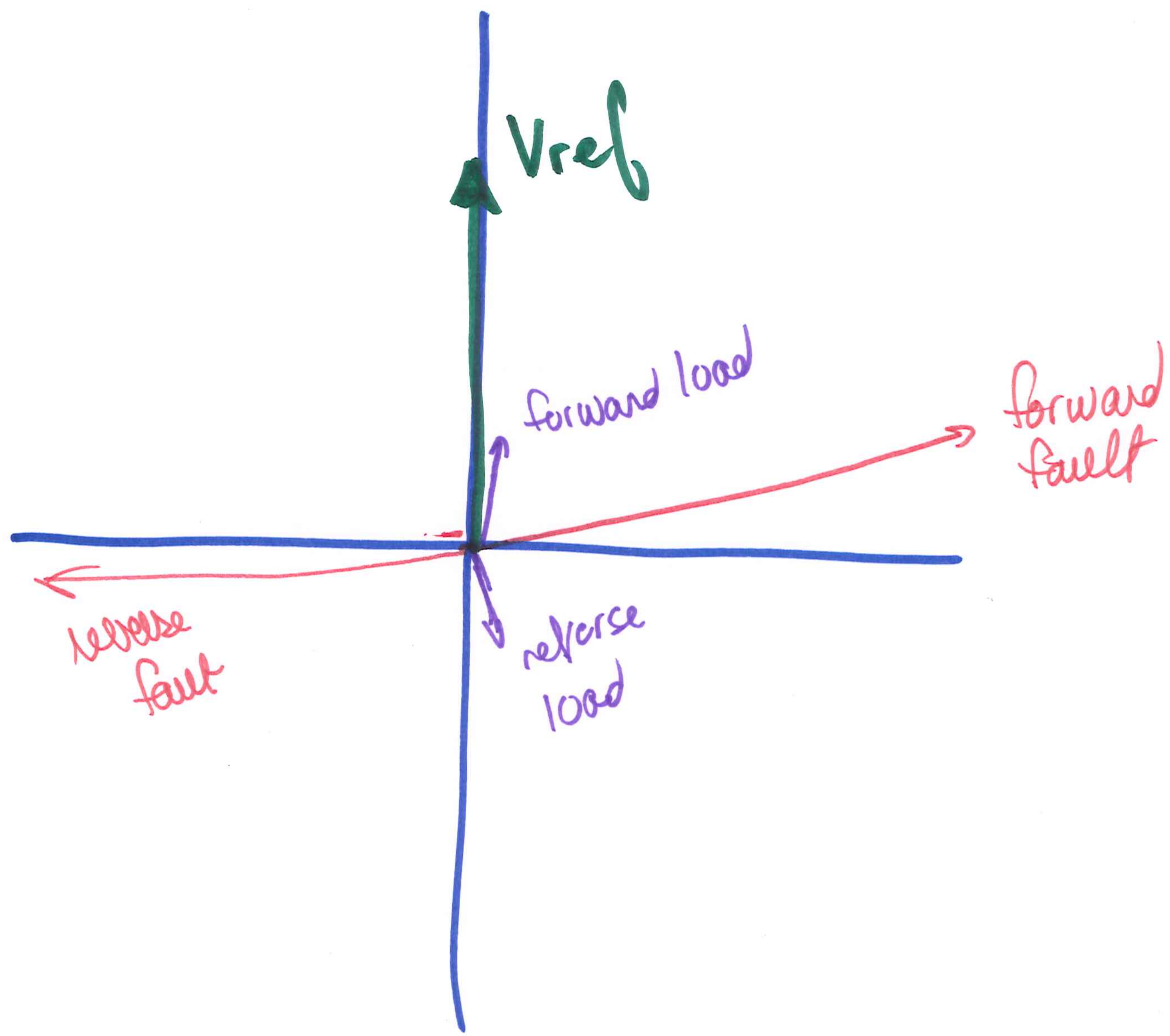
- Need a stable angle reference
  - something that doesnt move as much as angle of current
  - Voltage angles dont change as much
    → direction based on angle of current compared to voltage




Vref
forward load
forward fault
reverse fault
reverse load

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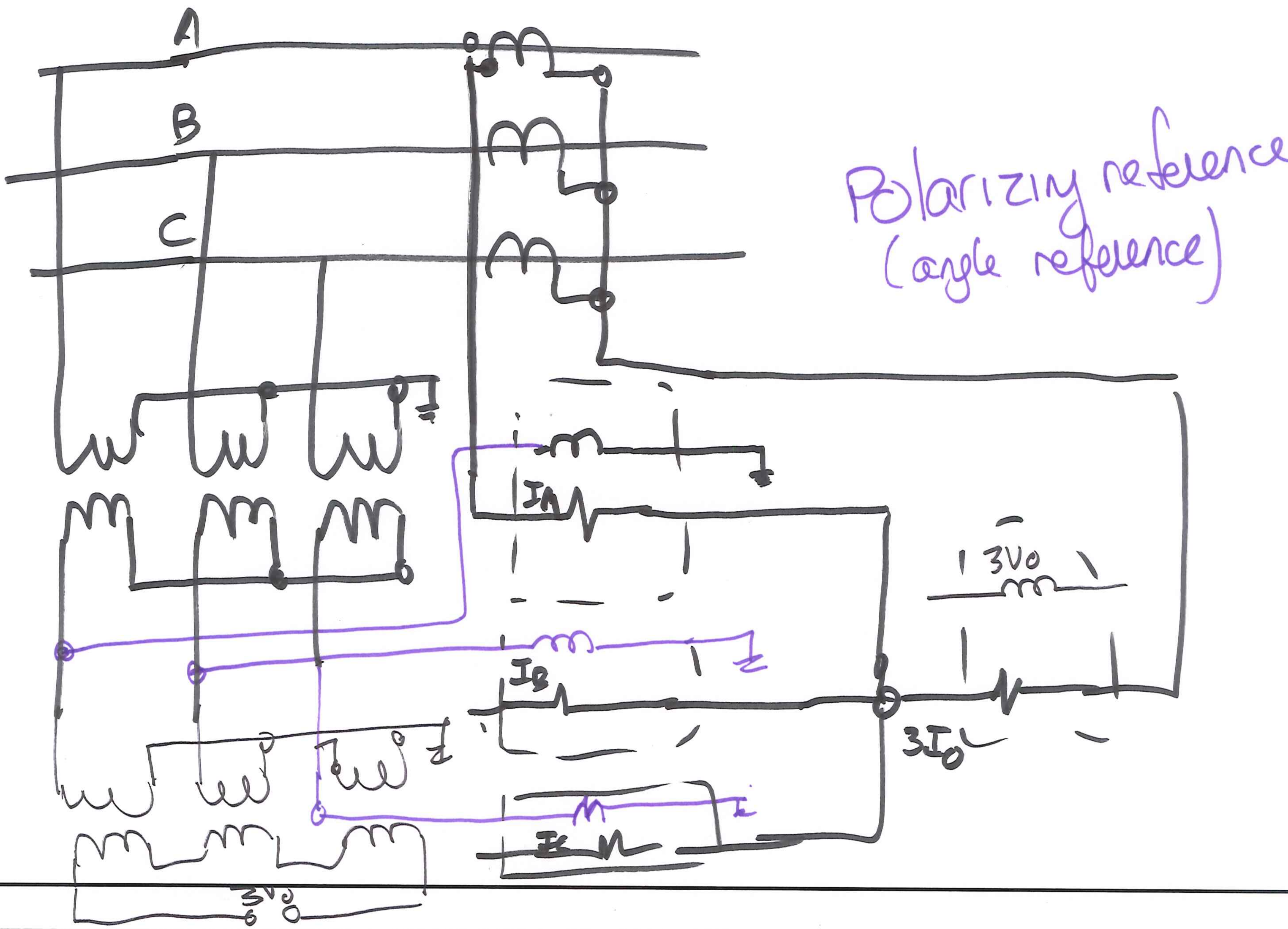

Self polarized directional

$$T_{67} = \underbrace{|V_{ref}|}_{V_{AG}} |I_A| \cos(\theta_V - (\theta_I + MTA))$$

MTA: typically angle of line impedance; max torque angle