ECE 525

POWER SYSTEM PROTECTION AND RELAYING

SESSION no. 16

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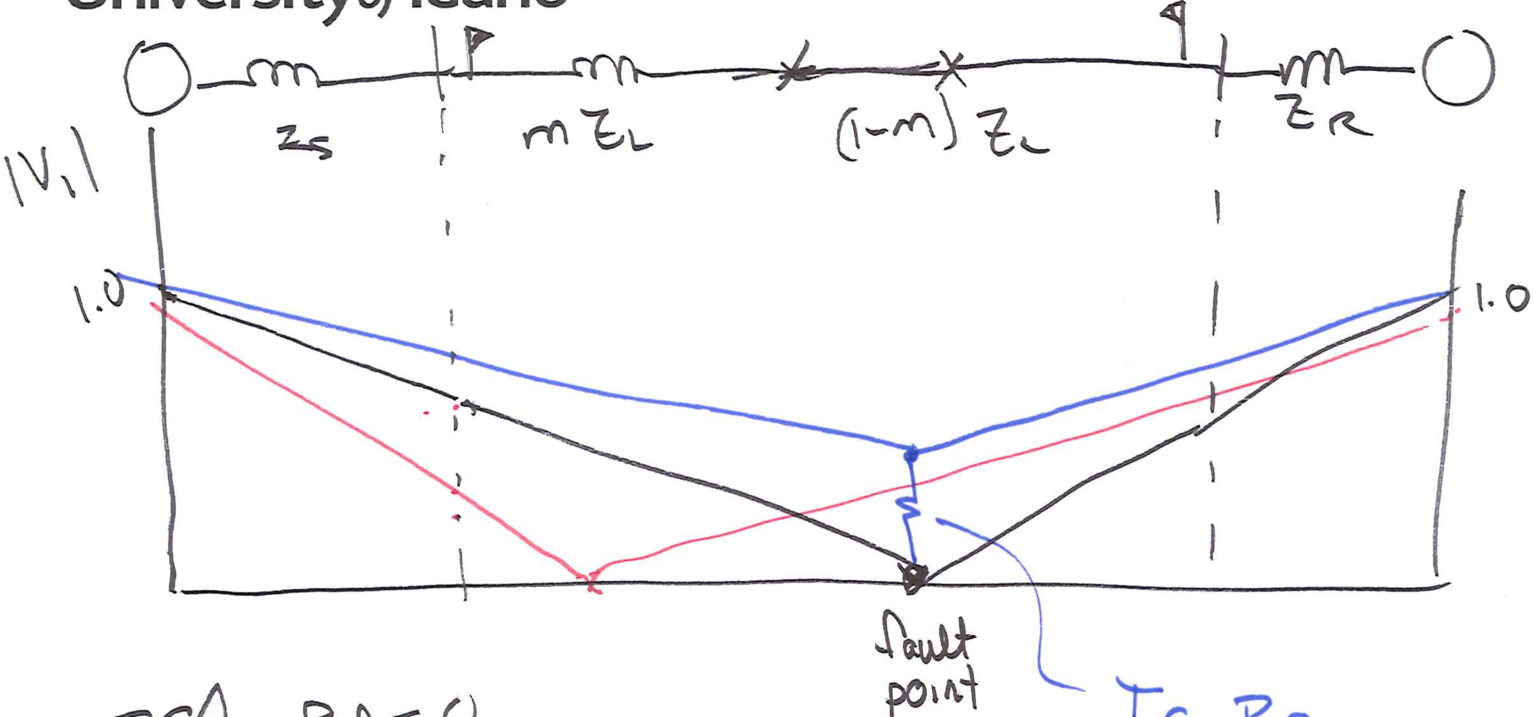
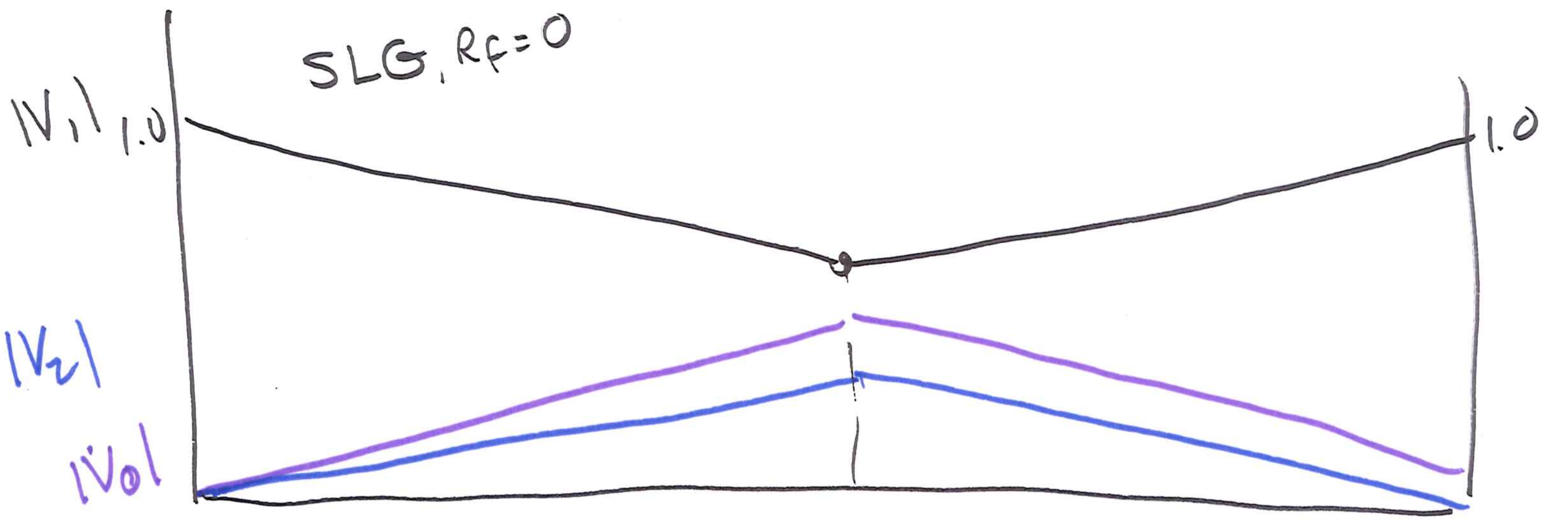


3∅ - $R_f = 0$

SLG, $R_f = 0$



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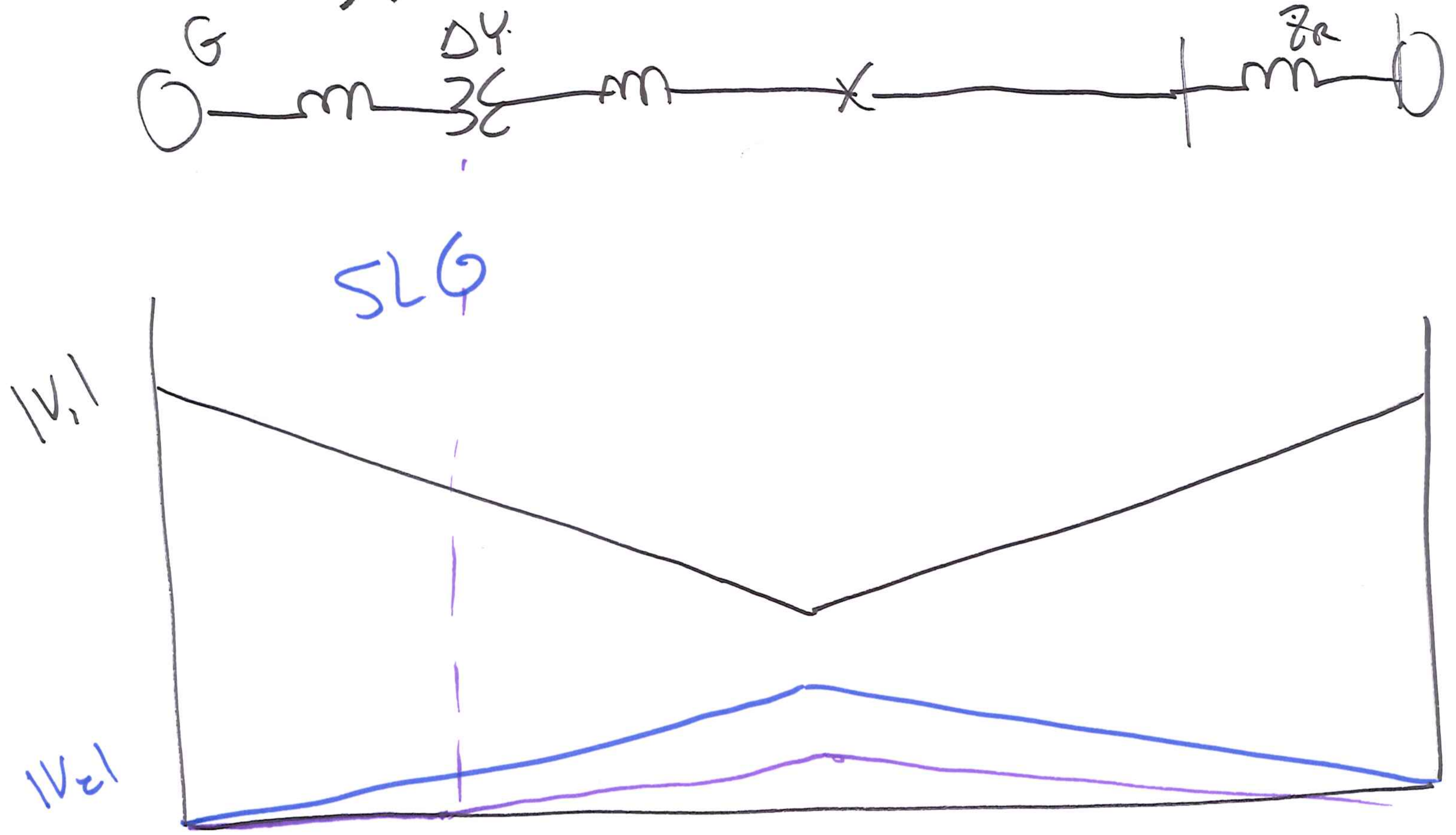

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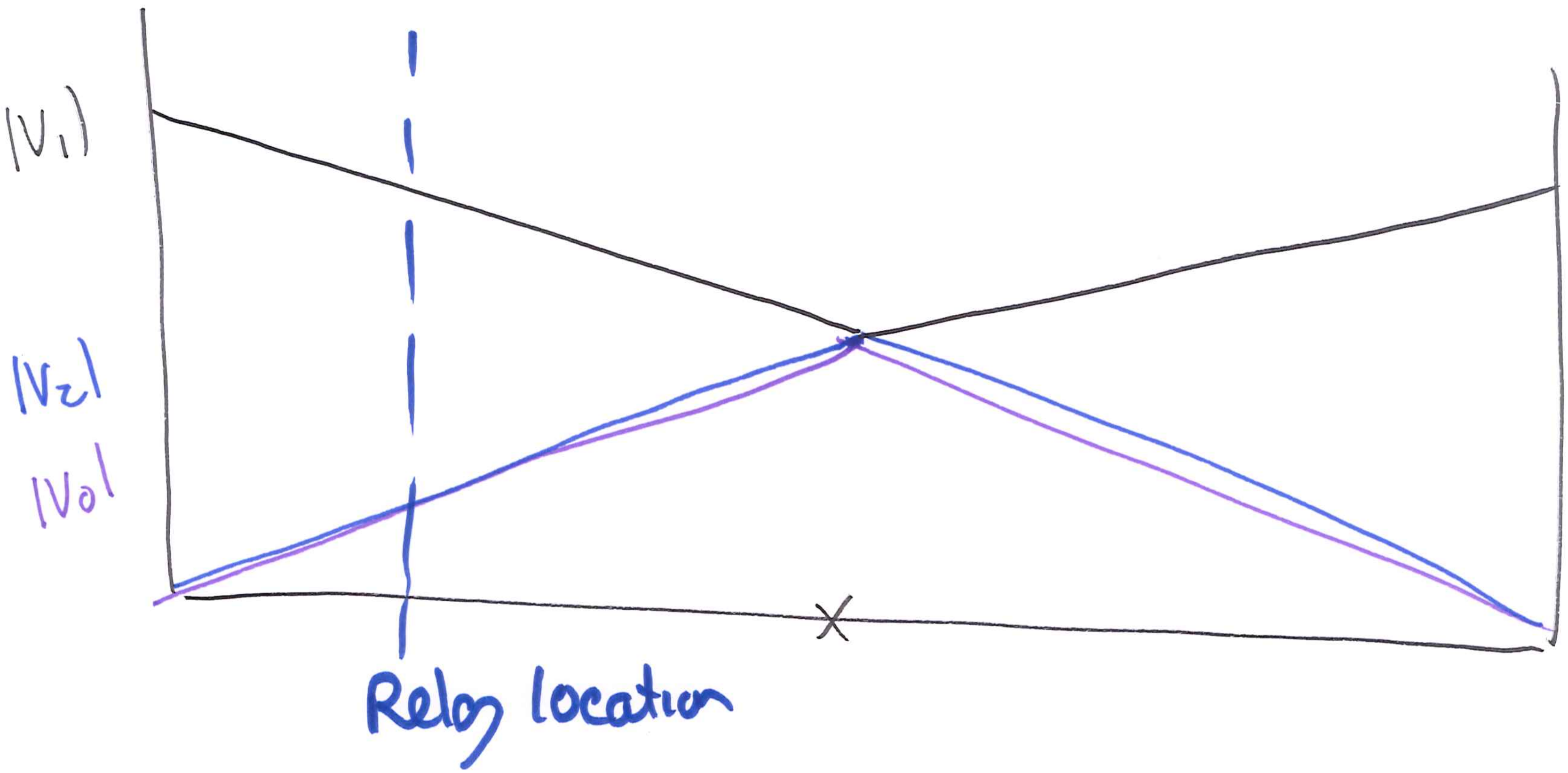
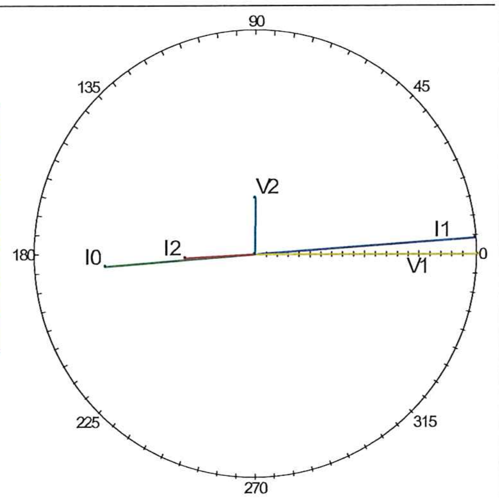
DLG - $R_f = 0$



C Symmetrical Component View of a C-Phase Open Fault

Component	Magnitude	Angle
Ic0	69	184
Ic1	101	4
Ic2	32	183
Vc0	0	162
Vc1	79	0
Vc2	5	90



One Phase Open (Series) Faults

- Voltage
  - » No zero sequence voltage
  - » Negative 90° out of phase with positive sequence
- Current
  - » Negative and zero sequence 180° out of phase with positive sequence

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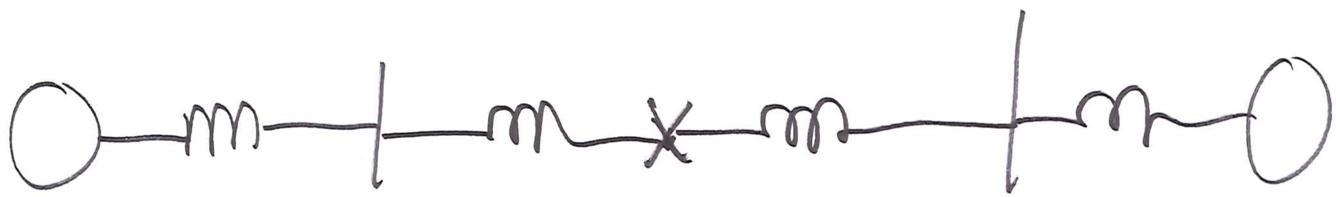
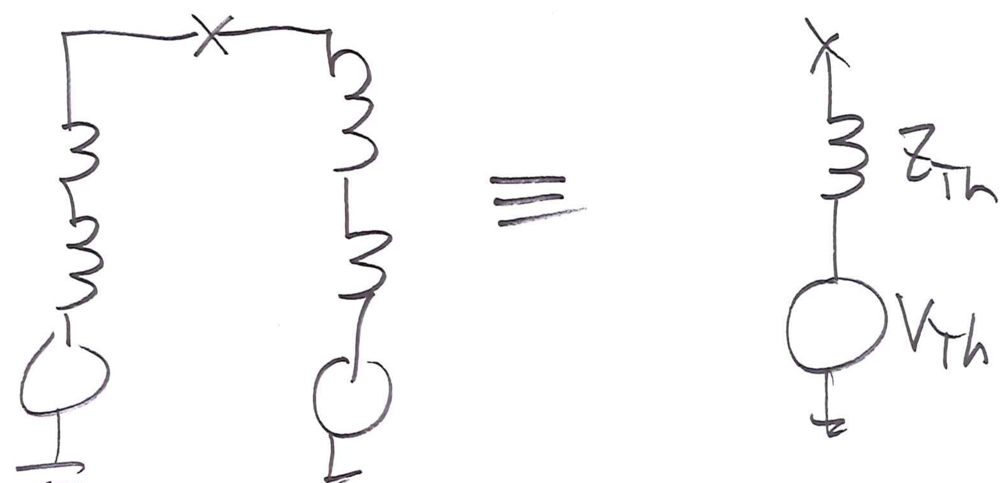
phase open (series imbalance)

- Requires 2 port Thevenin equivalent circuits



single port equiv



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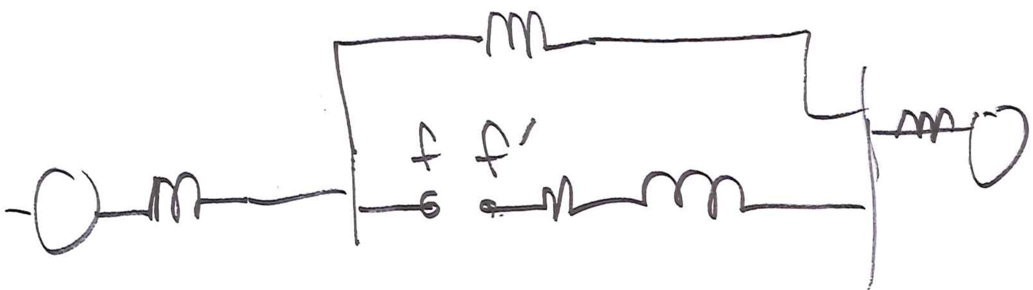
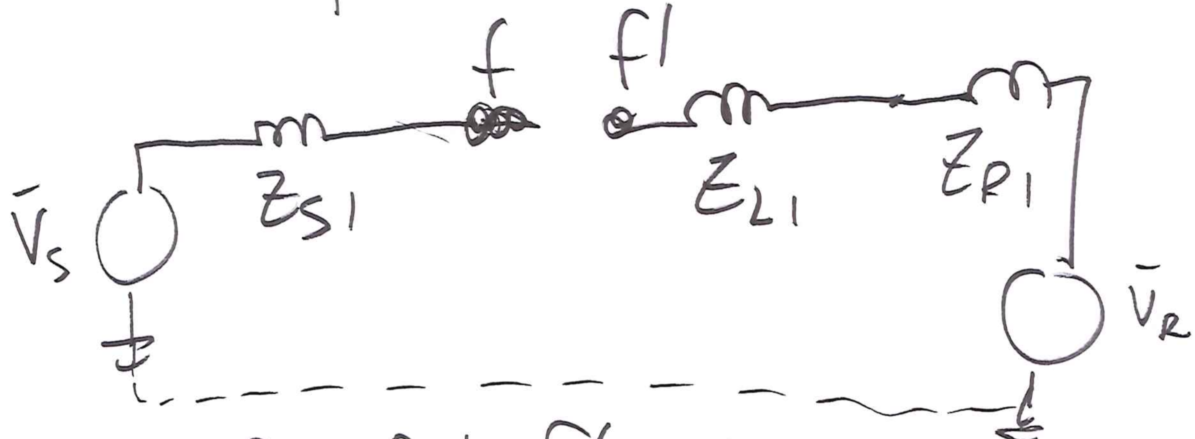
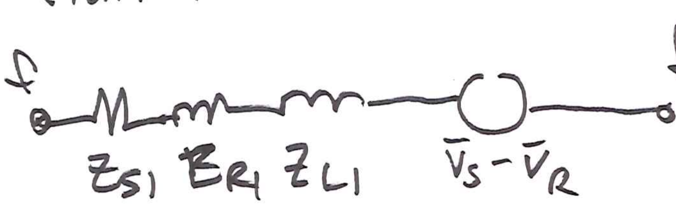


① w/o parallel line

Pos Seq Equiv

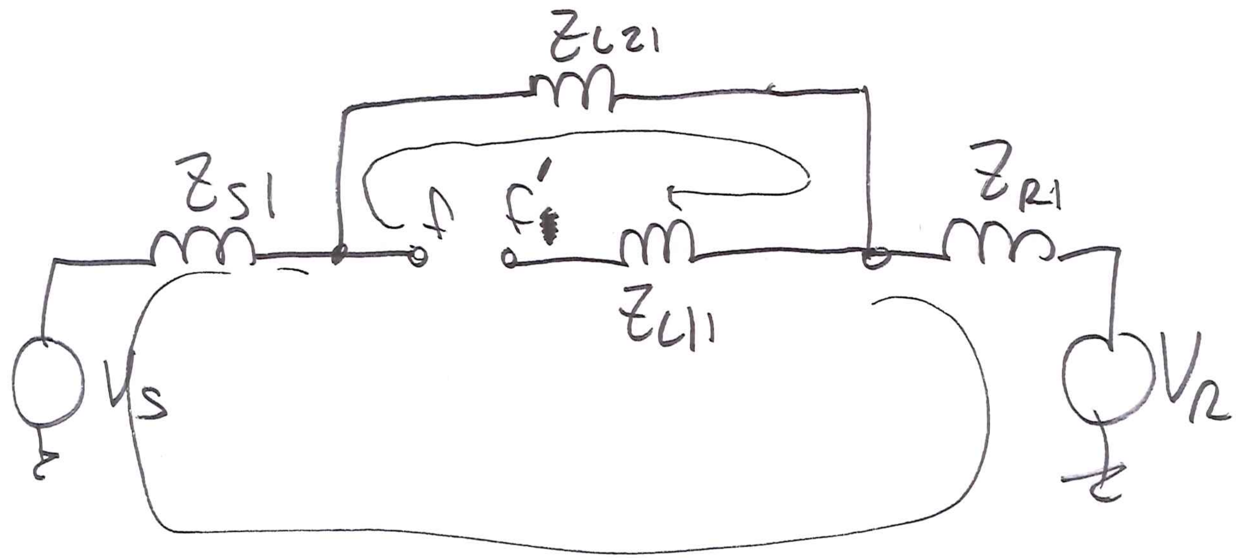


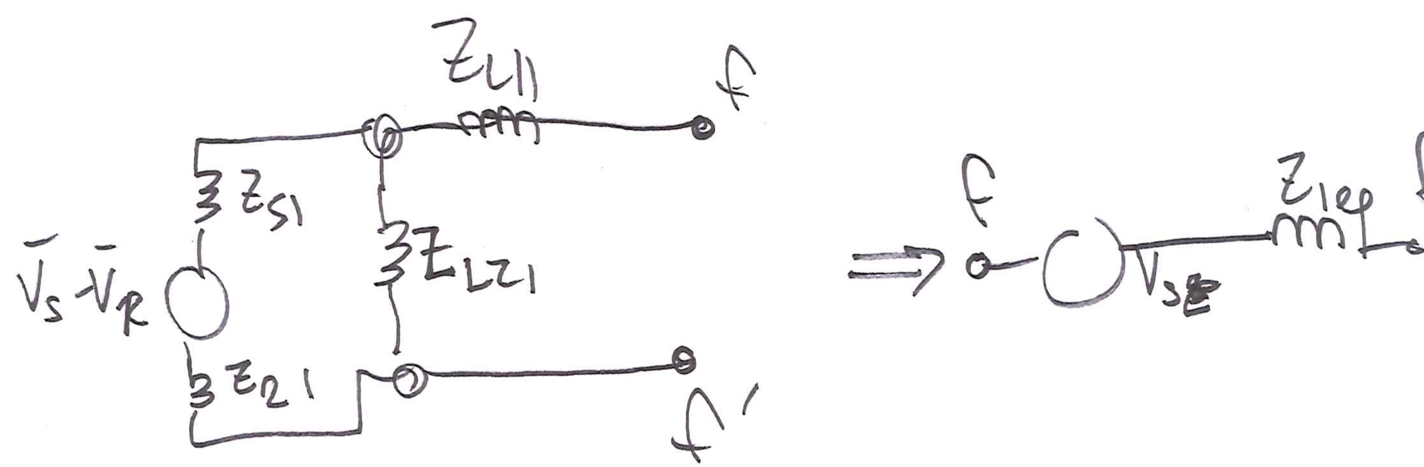
path from f to f'



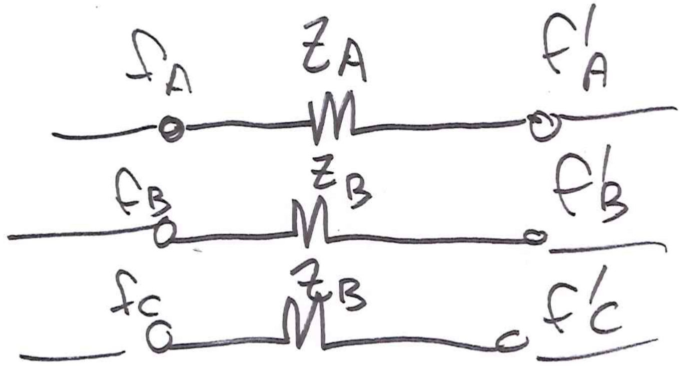
→ Assuming $\bar{V}_S \neq \bar{V}_R$ (load flow)

(2) Add parallel line

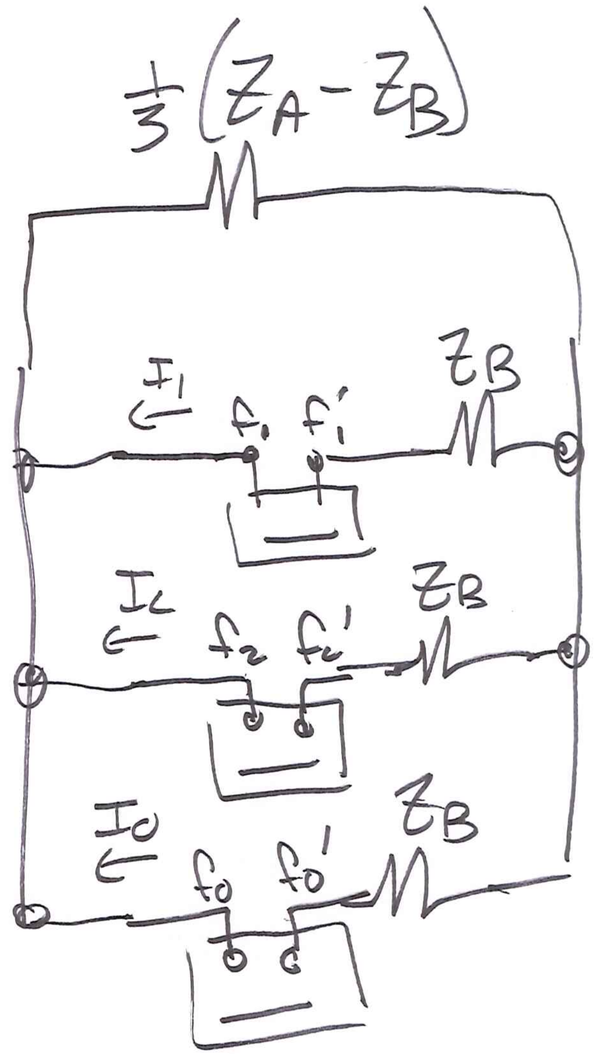




General sequence connection for series fault



$Z_B = Z_C$



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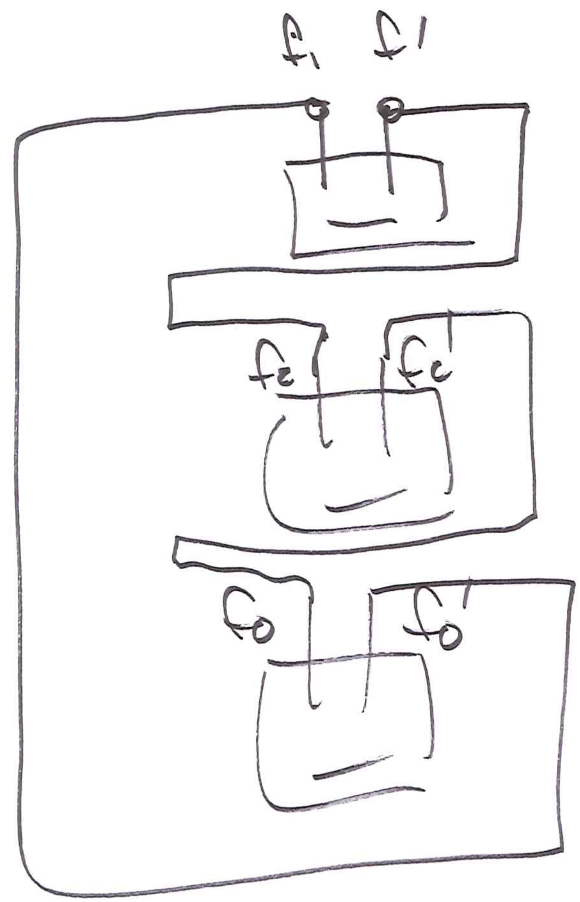
Special case of 1 phase closed, 2 open



$I_1 = I_2 = I_0$

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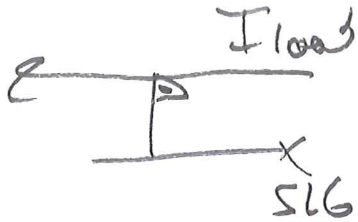
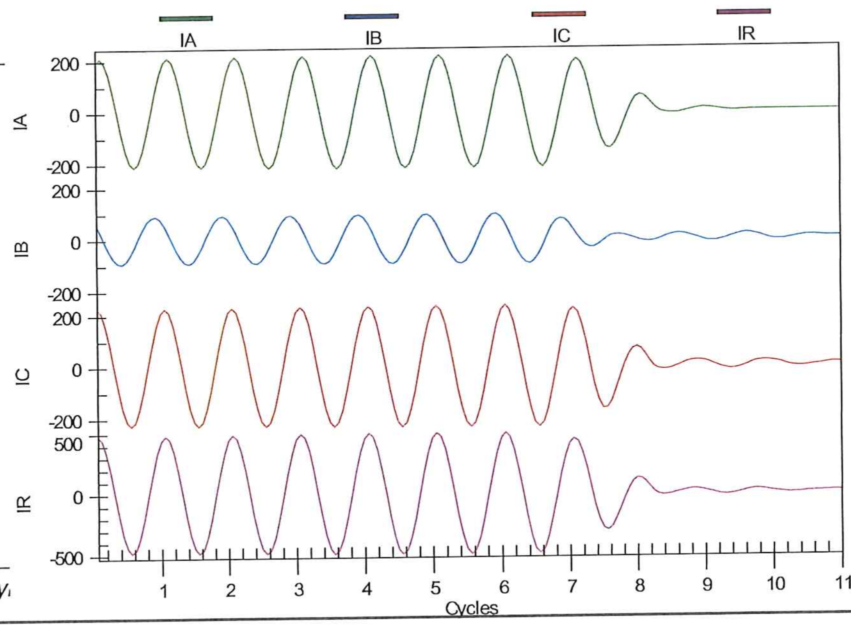
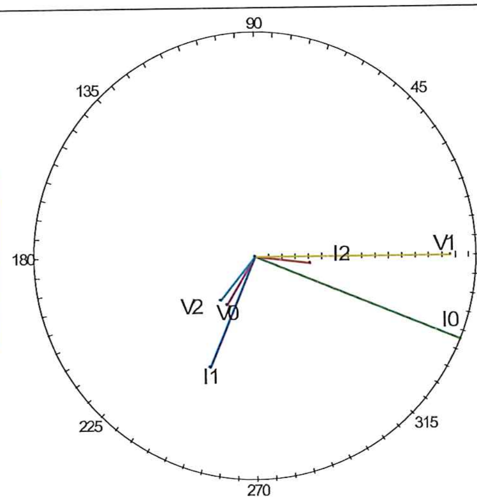


What About This One?

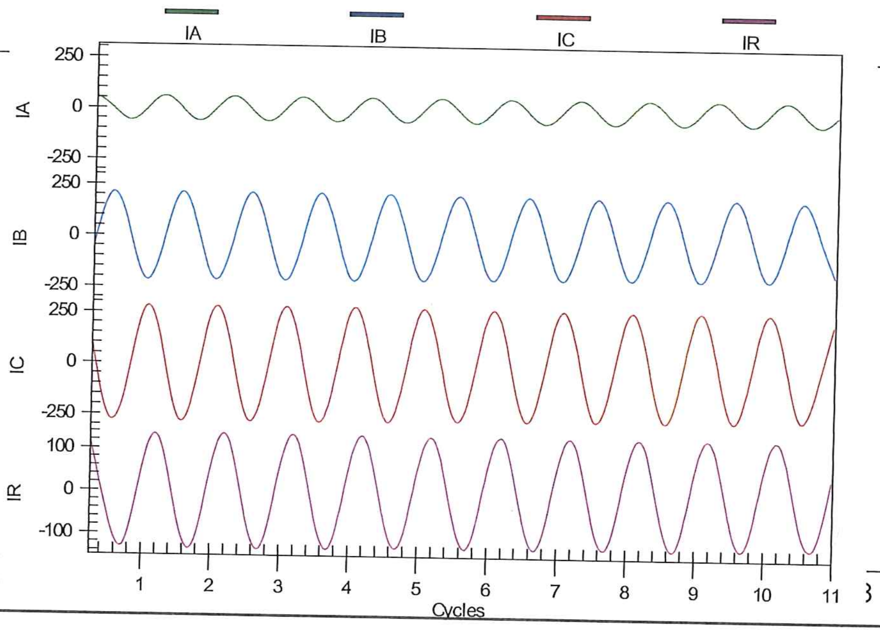


Ground Fault with Reverse Load

Ic0	164	-22
Ic1	89	-113
Ic2	41	-6
Vc0	4	-123
Vc1	38	0
Vc2	6	-130

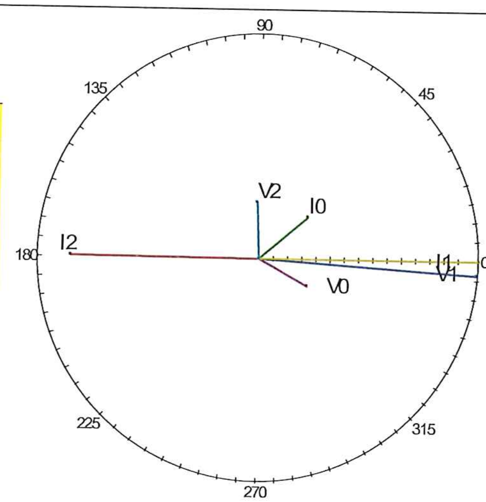


Finally, The Last One!



Fault on Distribution System with Delta – Wye Transformer

Component	Magnitude	Angle
Ic0	45	40
Ic1	153	-4
Ic2	132	180
Vc0	0.5	331
Vc1	40	0
Vc2	0.5	93



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Apparatus Models: Transformers

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- Normally model as series impedance from winding resistance and leakage reactance
- Positive and negative impedances equal
- In a Y-Δ transformer that phase shift is in the opposite direction for negative sequence

Zo - see below

Transformers (continued)

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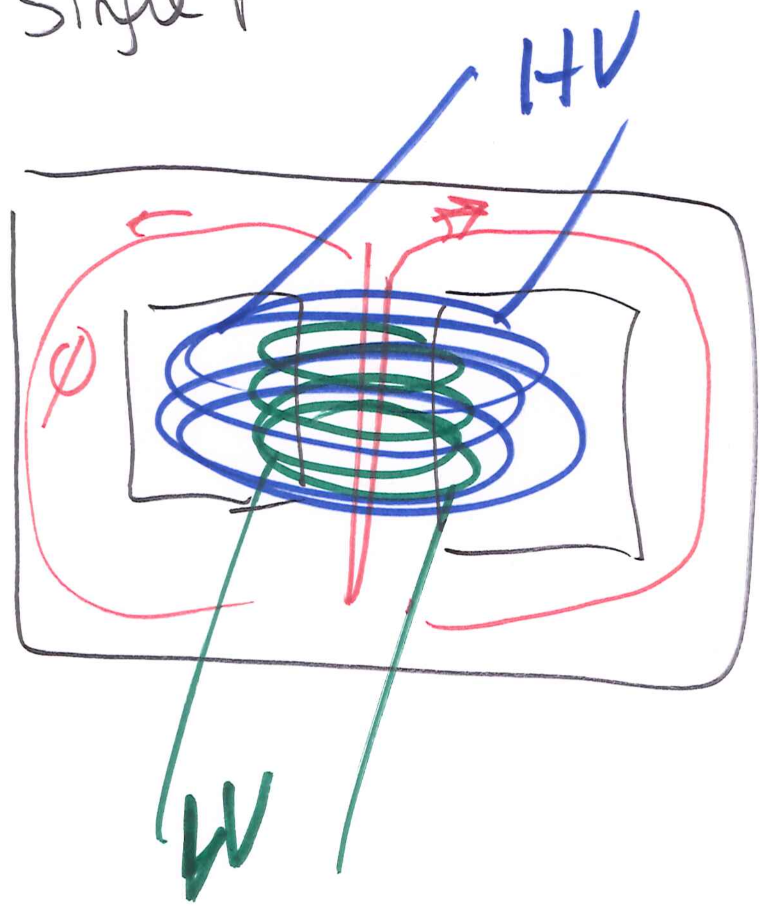
- Zero sequence impedance of the transformer depends on core construction
- $X_0=X_1$ for single phase cores
- $X_0=X_1$ for 5 leg or shell type core
  - Both have similar path for zero sequence current

Single phase core



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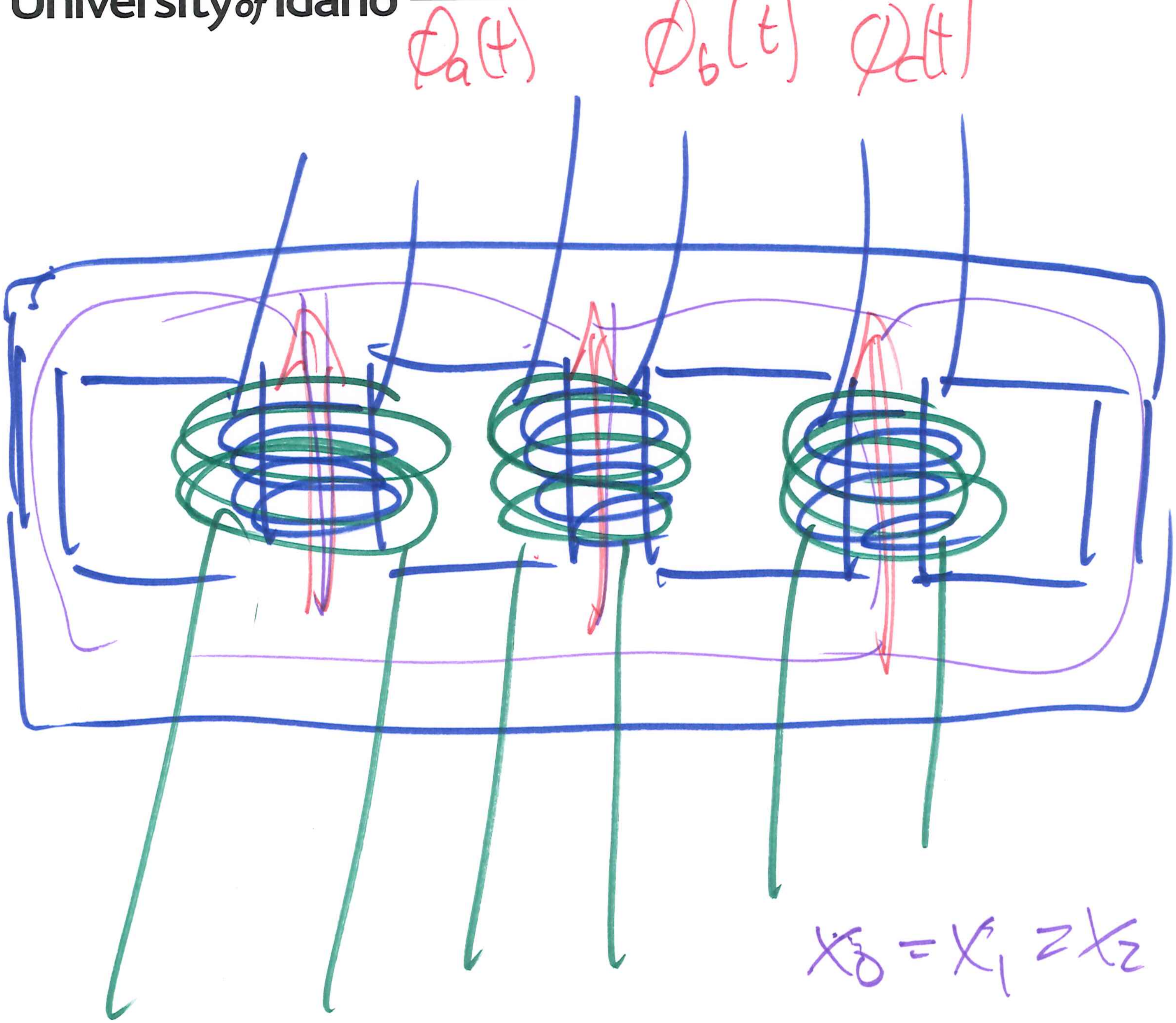
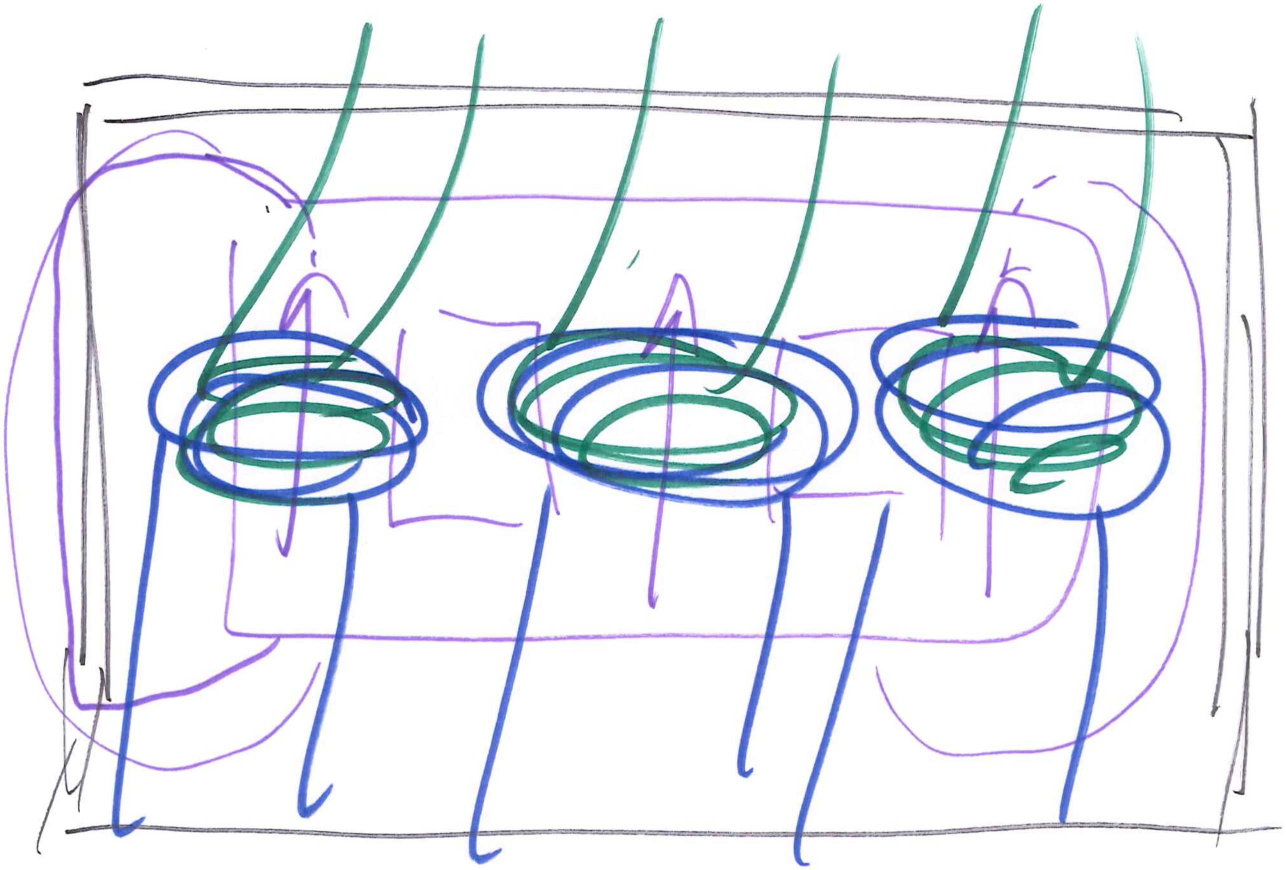
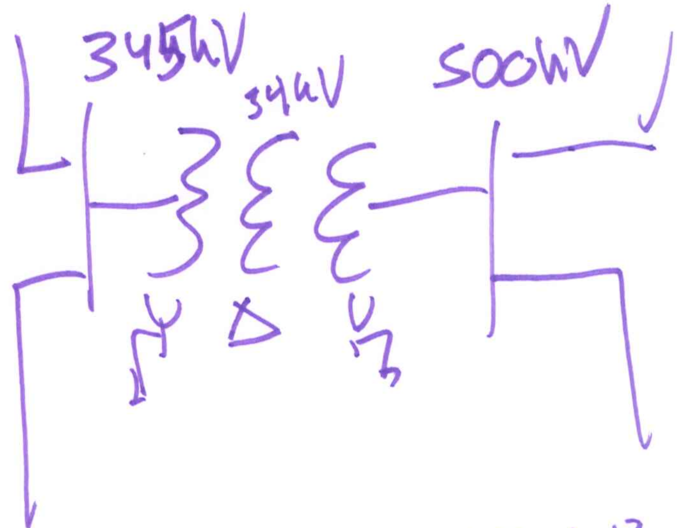
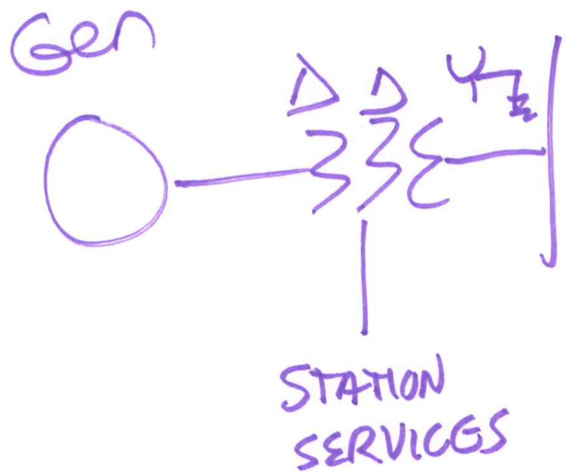


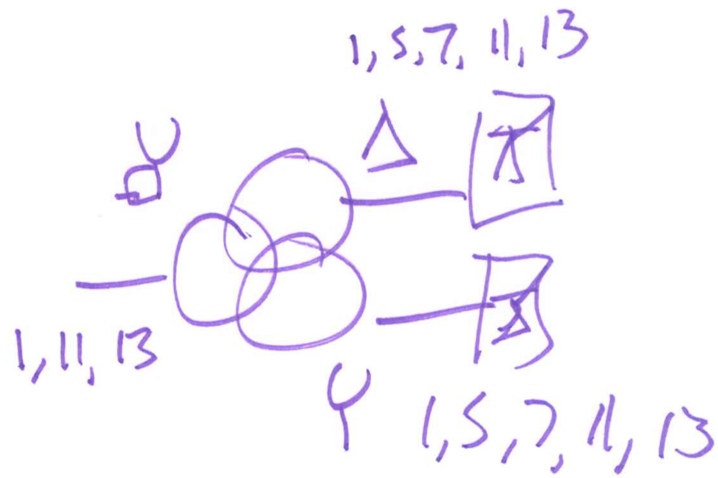
$X_0 = X_1 = X_2$



$x_1 = x_2$


345kV
34kV
500kV
Δ


Gen
Δ Δ
STATION
SERVICES


1, 5, 7, 11, 13
Δ
1, 11, 13
1, 5, 7, 11, 13

Transformer Connections

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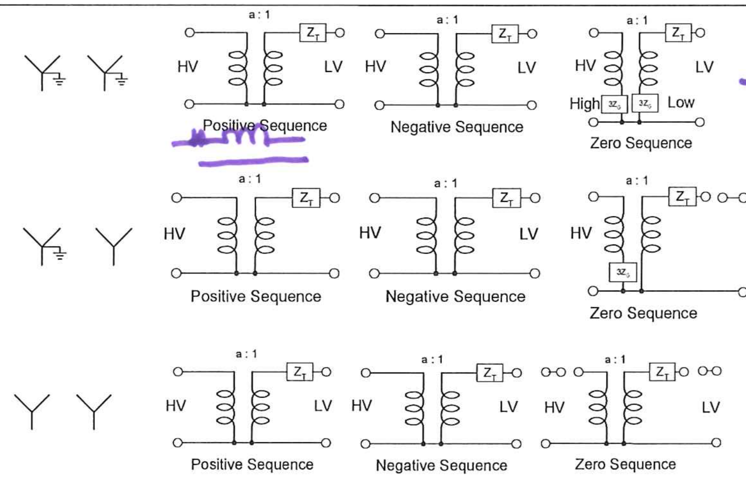

Sequence Models of Apparatus

Fall 2018

More Transformer Connections

ECE525

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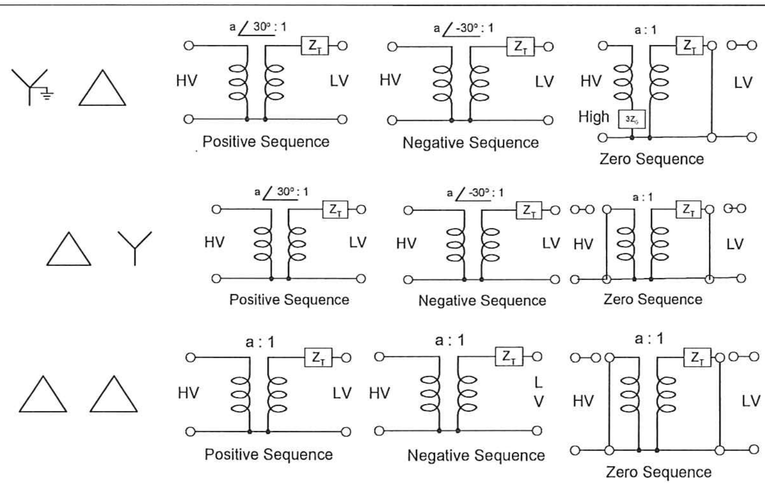

Sequence Models of Apparatus

Fall 2018

Transformers with Tertiaries

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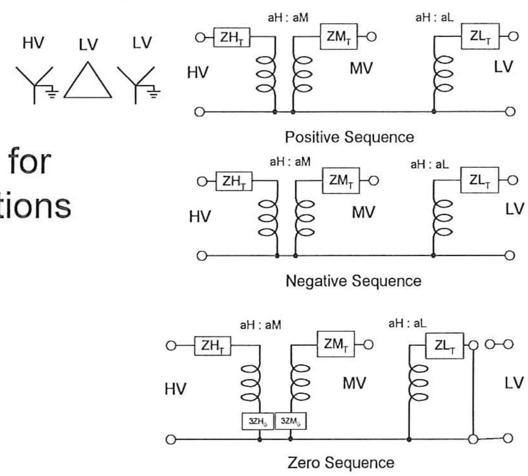
Lecture 16

- See Fig A4.2.3 for more configurations



Per Unit Equivalents (solid grounding)

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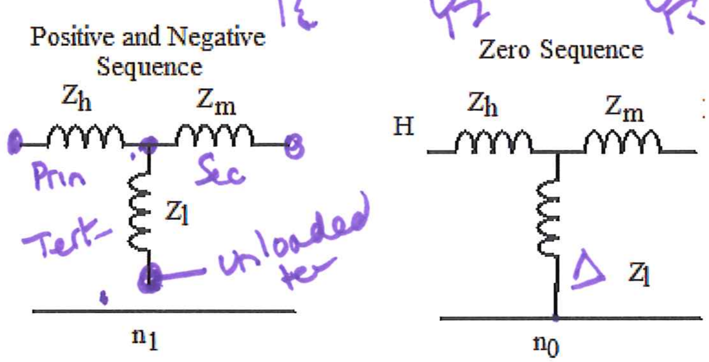
Lecture 16



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Calculating Z_h, Z_m and Z_l

- 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

- $Z_1=Z_2$ -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