University of Idaho

ECE 523
Symmetrical Components

Session 20

EMTP Variants

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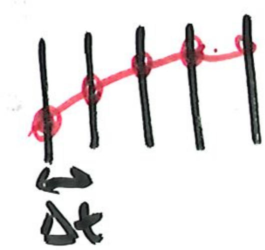
- Original version mainly modeled RLC elements switches, ideal sources and lines
- Many extensions and several versions
  - » ATP: Alternate transients program (http://www.emtp.org)
  - » EMTP-RV (http://www.emtp.com) latest from DCG
  - » EMTDC: student version available free from their web site (http://www.pscad.com/)
  - » RTDS: Real time digital simulator (cost), Hypersim (Opal-RT)
  - » SimPowerSystems blockset for Matlab

Intro to EMTP simulation 7 Fall 2023

7



Using EMT Programs

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- Outputs are voltage, current, power, and energy versus time
- Control variables are available if controls are modeled
- Can model simple controls using EMTs control models or can interface to FORTRAN (in some cases C or Matlab too)
  - » Programs have internal control modeling
  - » Graphical user interface

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8

L20 2/23

The ATP Version

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- ATP is essentially free. A license application needs to be filled out (do not choose student license)
  - » https://www.atp-emtp.org/
  - » The purpose is to limit access to parties that have participated in "EMTP-Commerce"

ATPDraw

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- Available for download from ATP distribution sites
- Follow link for ATPDraw for information about the program
  - » Latest versions are version 7.4
  - » File format not backward compatible
  - » http://www.atpdraw.net/ (ATPDraw only, not ATP itself)
- Get the program and the patch files (update to fix bugs in executable)
- Manual and introduction presentation for download

L20 3/23

PSCAD/EMTDC

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- Education version available in ECE labs
- Free Student Edition (15 node limit)
  - » Go to: http://www.pscad.com/
  - » Create account and get set up to download
    - – Download the Program itself
    - – Includes free Fortran Compiler
      - Need unless you have compatible one installed
- Website also has tutorials
- Remote access on UI computers

11

EMTP-RV

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- Available in ECE labs
- Remotely available on University of Idaho computers
- Tutorials available at

https://www.emtp-software.com/

12

L20 4/25

Validation of Models… and Results

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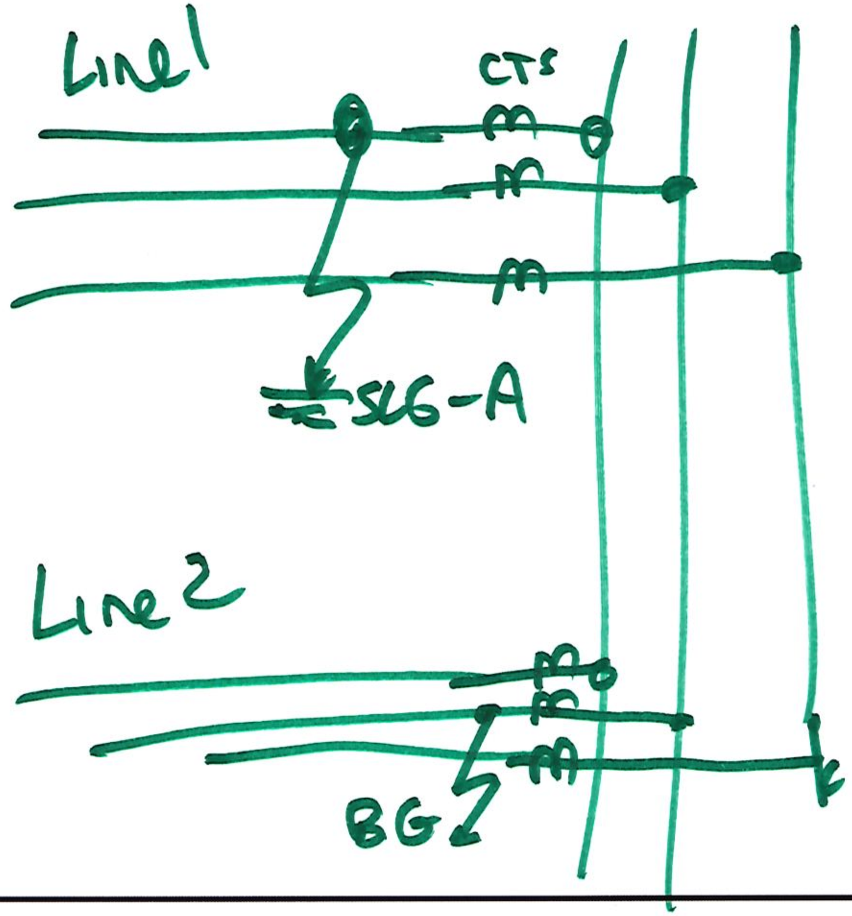
- Need to have a basic idea of what the transient response should look like
- Test your system with some very predictable cases
- Start from steady-state operating point
- Understanding behavior will be one of the focuses of this course

Simultaneous Faults

- Almost all faults are a single event at a single location



→ two close together faults on different lines

- faults not on system very long

- sometimes two faults are present at same time that are unrelated

  - or related - for example a fault that has a broken conductor → that falls to the ground

Analysis of Simultaneous faults

- for faults at one location or different locations

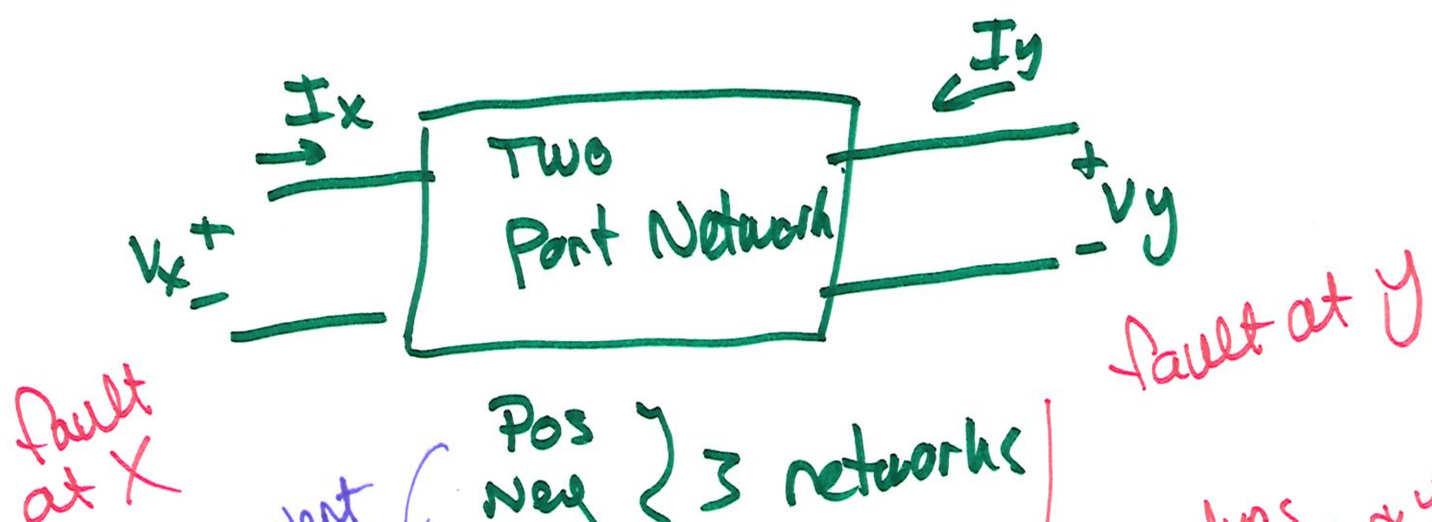
- 2 port Thevenin Equivalent
  - looking between locations

- we also need to translate between symmetrical component reference frames in some cases.

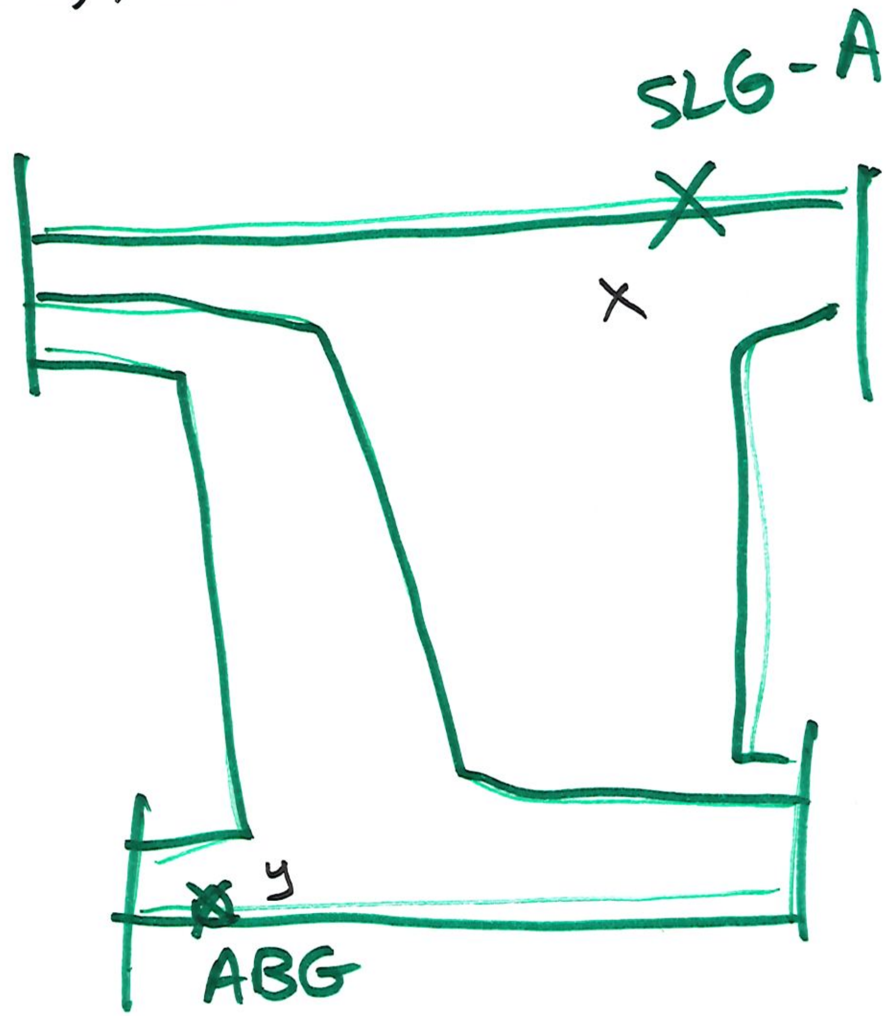
for example

- AG fault at one location → A ref components and BG at another one – B ref components

Two Port Networks



equivalent (Pos, Neg, Zero } 3 networks) connections between X & Y in power system


SLG-A
x
y
ABG

- Three types of two port networks for circuit analysis (Section 9.1 & 9.2 in Anderson book)

1. Impedance type (Z-type)

$$\begin{bmatrix} V_{x_{012}} \\ V_{y_{012}} \end{bmatrix} = \begin{bmatrix} Z_{xx_{012}} & Z_{xy_{012}} \\ Z_{yx_{012}} & Z_{yy_{012}} \end{bmatrix} \begin{bmatrix} \bar{I}_{x_{012}} \\ \bar{I}_{y_{012}} \end{bmatrix}$$

→ 3 — one each for pos, neg, zero

2. Admittance (Y-type)

$$\begin{bmatrix} I_x \\ I_y \end{bmatrix} = \begin{bmatrix} \bar{Y}_{xx} & \bar{Y}_{xy} \\ \bar{Y}_{yx} & \bar{Y}_{yy} \end{bmatrix} \begin{bmatrix} V_x \\ V_y \end{bmatrix}$$

3. Hybrid → (H-type) (H-parameters)

$$\begin{bmatrix} V_x \\ I_y \end{bmatrix} = \begin{bmatrix} H_{xx} & H_{xy} \\ H_{yx} & H_{yy} \end{bmatrix} \begin{bmatrix} I_x \\ V_y \end{bmatrix}$$

→ some work better series faults
others for shunts

→ Also voltage source versus current
source

<u>Example</u> : fault X is SLG on phase A

fault Y is BC fault

<u>SLG on A</u>

- A ref components
- $I_0 = I_1 = I_2$ at <u>fault locat</u>ion

  $V_0 + V_1 + V_2 = 3 I_0 R_f$

BC $\quad I_1 = -I_2$

$V_1 - V_2 = I_1 R_f$

A ref components

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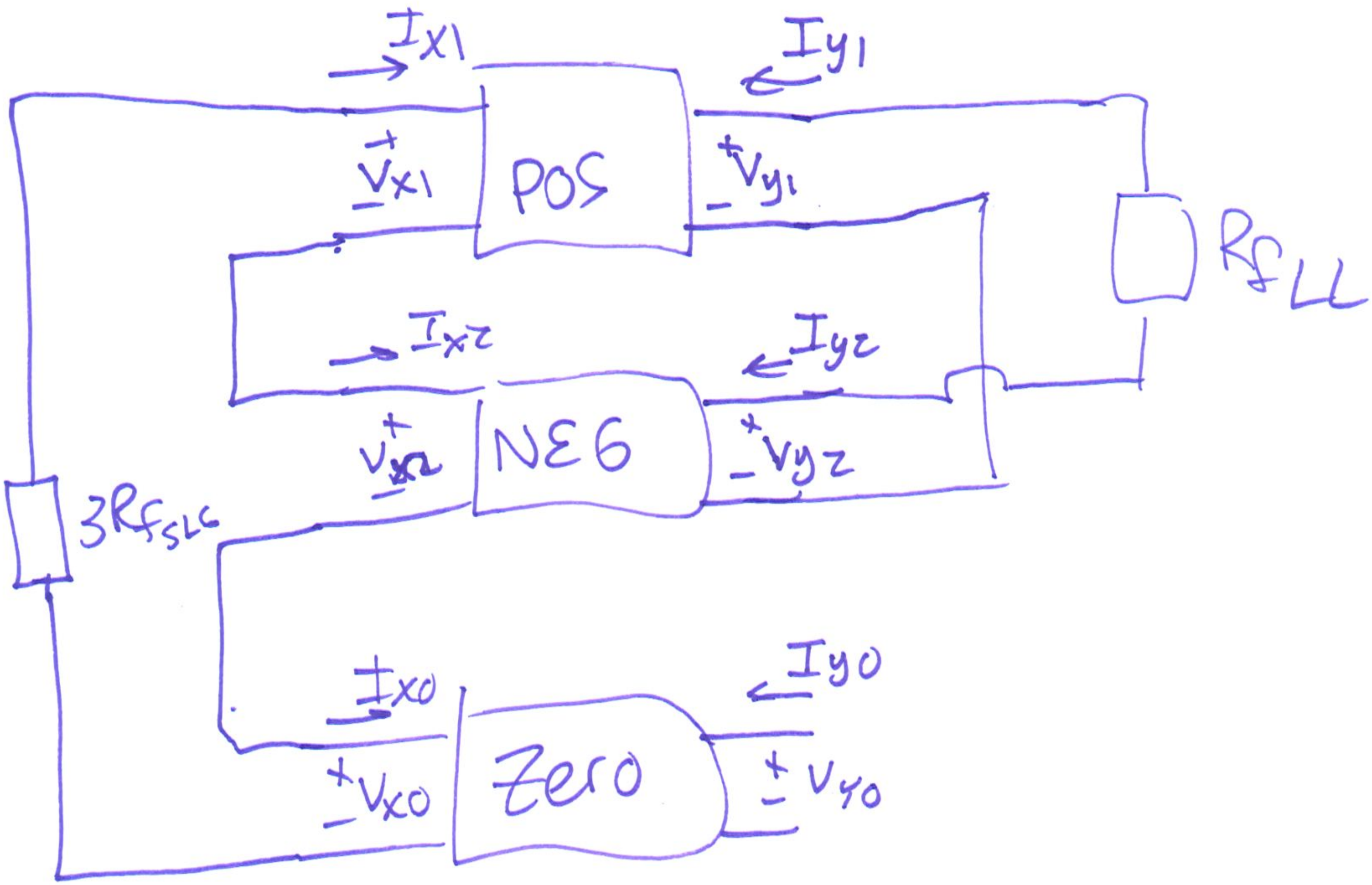

POS
NEG
Zero
I_{x1}
I_{y1}
V_{x1}
V_{y1}
I_{x2}
I_{y2}
V_{x2}
V_{y2}
I_{x0}
I_{y0}
V_{x0}
V_{y0}
R_{fLL}
$3R_{fSLG}$

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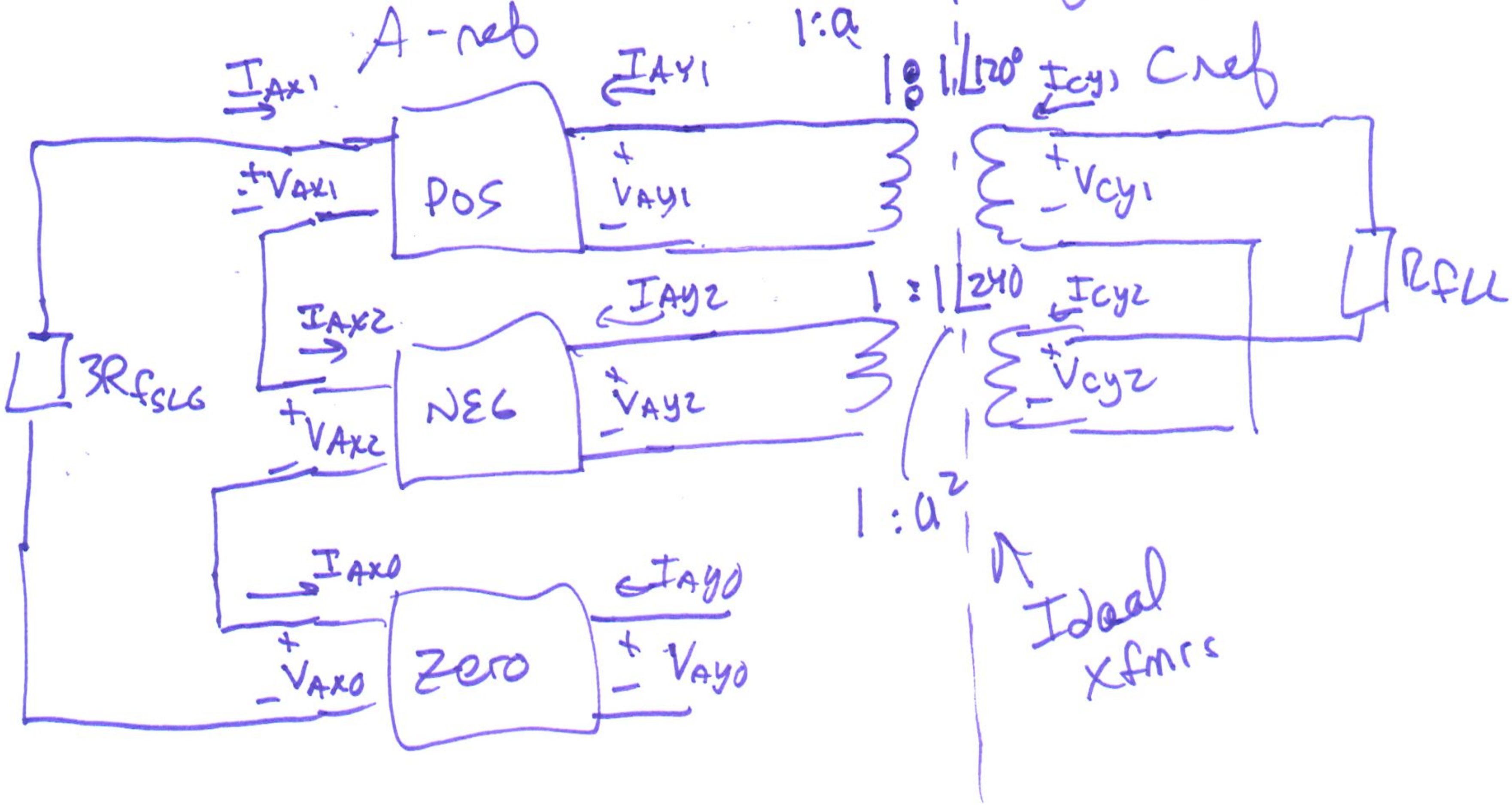
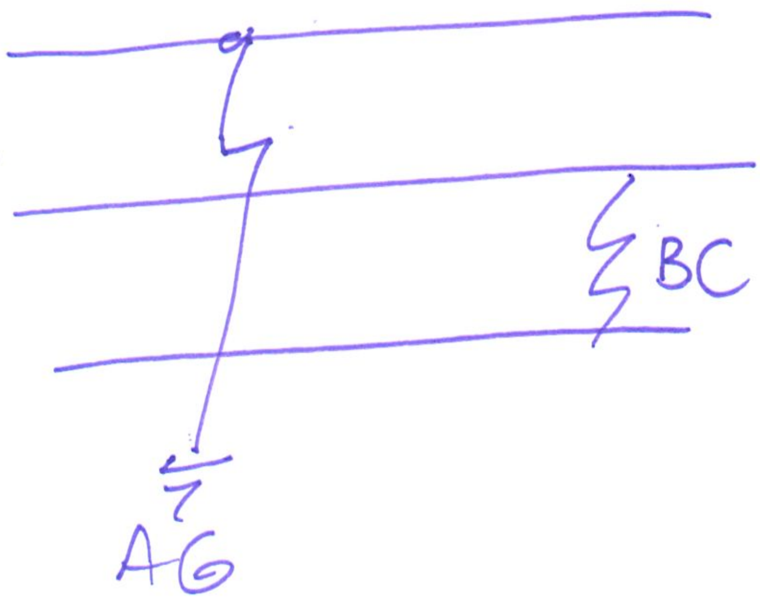
Suppose the LL fault is AB fault → C ref components



Example → AG & BC at same location



ABC constraints

SLG: $V_{AG} = R_G I_{AG}$

LL $I_{Bf} = -I_{Cf}$

$V_{BG} = V_{CG} + R_f I_{Bf}$

$$\begin{bmatrix} I_0 \\ I_1 \\ I_2 \end{bmatrix} = A_{012}^{-1} \begin{bmatrix} I_{Af} \\ I_{Bf} \\ I_{Cf} \end{bmatrix}$$

$I_{Cf} \rightarrow -I_{Bf}$

$$I_0 = \frac{1}{3}\left[I_{Af} + I_{Bf} - I_{Bf}\right] = \frac{I_{Af}}{3}$$

$$I_1 = \frac{1}{3}\left[I_{Af} + a I_{Bf} - a^2 I_{Bf}\right]$$

$$I_2 = \frac{1}{3}\left[I_{Af} + a^2 I_{Bf} - a I_{Bf}\right]$$

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$$I_1 + I_2 = \frac{1}{3}\left[2 I_{Af} + B_f\left[a - a^2 + a^2 - a\right]\right)$$

$$I_1 + I_2 = \frac{2}{3} I_{Af} = 2 I_0$$

$$V_{AG} = R_G I_{Af}$$

$$V_{BG} = V_{CG} + R_{fBC} \cdot I_{Bf}$$

for the moment let $R_G = R_{fBC} = 0$

$$V_{AG} = 0 = V_{A0} + V_{A1} + V_{A2}$$

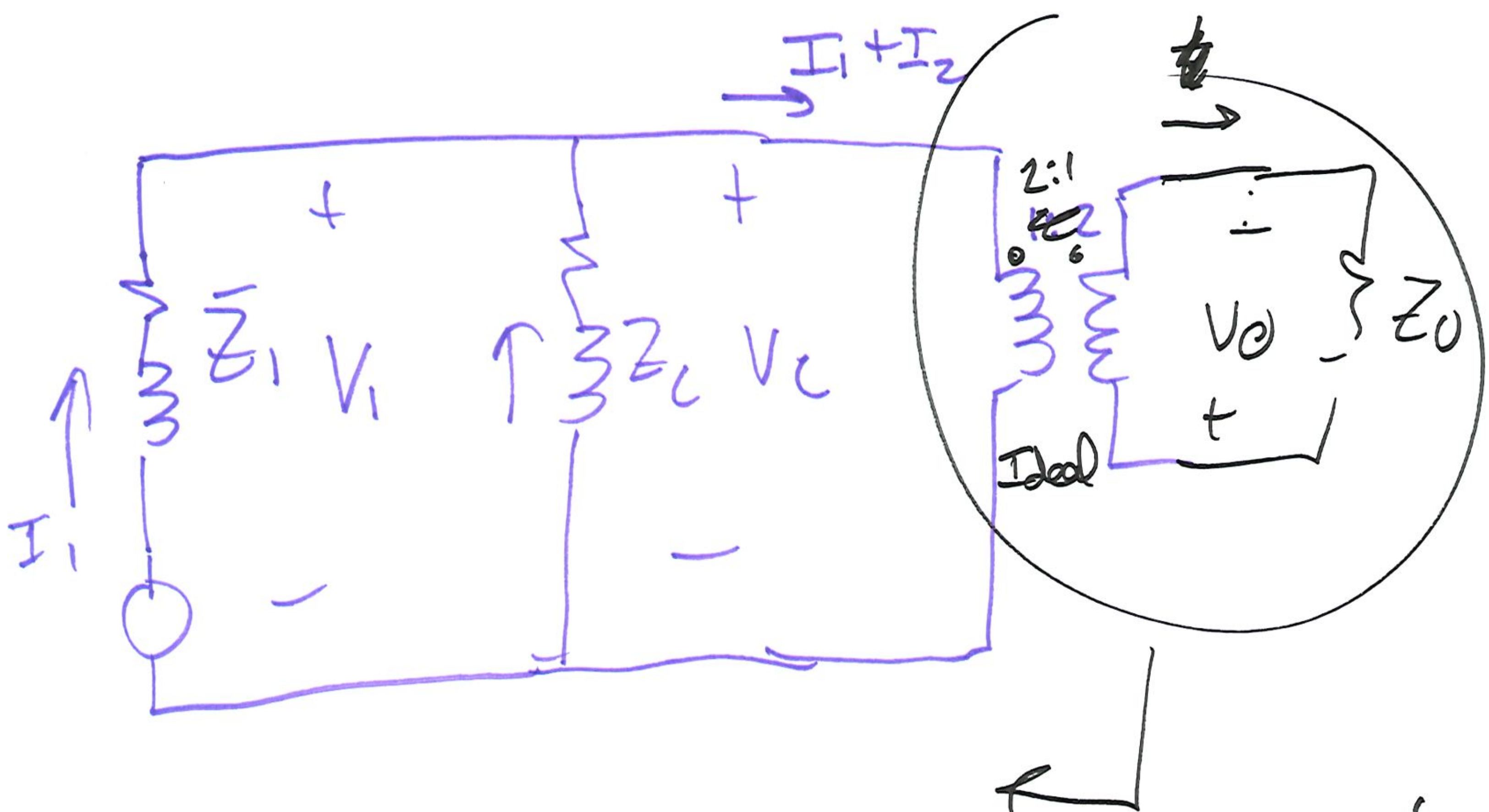
$$V_{BG} = V_{CG} \Rightarrow V_{A1} = V_{A2}$$

Then $V_{AG} = 0 = V_{A0} + V_{A1} + V_{A2}$

$$0 = V_{A0} + 2V_{A1} = V_{A0} + 2V_{A2}$$

$$V_{A1} = V_{A2} = -\frac{V_{A0}}{2}$$

Since same location we can use single port equivalent



refer across transform

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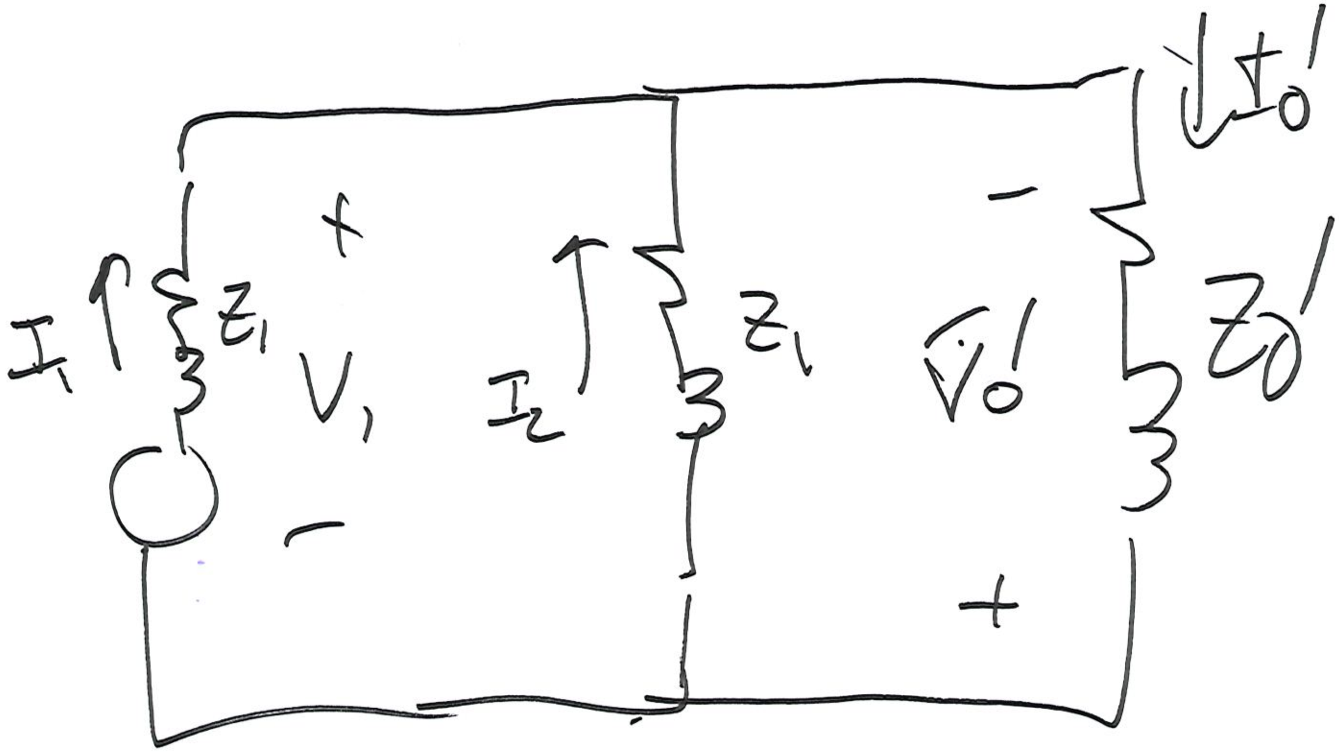

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$$Y_{Bus0}(M) := \begin{bmatrix} \frac{1}{Z_{S0}} & 0 & 0 & 0 & 0 \\ 0 & \frac{1}{Z_{T10}} + \frac{1}{M \cdot Z_{L0}} & 0 & 0 & \frac{-1}{M \cdot Z_{L0}} \\ 0 & 0 & \frac{1}{(1-M) \cdot Z_{L0}} + \frac{1}{Z_{T20}} & 0 & \frac{-1}{(1-M) \cdot Z_{L0}} \\ 0 & 0 & 0 & \frac{1}{Z_{R0}} & 0 \\ 0 & \frac{-1}{M \cdot Z_{L0}} & \frac{-1}{(1-M) \cdot Z_{L0}} & 0 & \frac{1}{M \cdot Z_{L0}} + \frac{1}{(1-M) \cdot Z_{L0}} \end{bmatrix}$$

$$Z_{Bus1}(M) := Y_{Bus1}(M)^{-1}$$

$$Z_{Bus2}(M) := Y_{Bus2}(M)^{-1}$$

$$Z_{Bus0}(M) := Y_{Bus0}(M)^{-1}$$

Simultaneous AG and BC faults 30% of the way from Bus 1 to Bus 2

$I_1 + I_2 = 2 \cdot I_0$

$V_1 = V_2 = \frac{-1}{2} \cdot V_0$

$V_f := 1.0pu$ No load

$M := 0.3$

$$I_1 := \frac{V_f}{Z_{Bus1}(M)_{4,4} + \left[\frac{1}{Z_{Bus2}(M)_{4,4}} + \frac{1}{\left(Z_{Bus0}(M)_{4,4}\right)\cdot\frac{1}{4}}\right]^{-1}}$$

$|I_1| = 2.055\cdot pu$ $\quad$ $\arg(I_1) = -86.871\cdot deg$

$$I_2 := -I_1\cdot\left[\frac{\frac{\left(Z_{Bus0}(M)_{4,4}\right)}{4}}{Z_{Bus2}(M)_{4,4} + \frac{\left(Z_{Bus0}(M)_{4,4}\right)}{4}}\right]$$

$|I_2| = 0.55\cdot pu$ $\quad$ $\arg(I_2) = 91.613\cdot deg$

$$I_0 := \frac{I_1}{2}\cdot\left[\frac{Z_{Bus2}(M)_{4,4}}{Z_{Bus2}(M)_{4,4} + \frac{\left(Z_{Bus0}(M)_{4,4}\right)}{4}}\right]$$

$|I_0| = 0.752\cdot pu$ $\quad$ $\arg(I_0) = -86.316\cdot deg$

Z0'

→ correcty for my current constraints

$$\left(I_1 + I_2\right) - 2\cdot I_0 = 0$$

$V_1 := V_f - I_1\cdot Z_{Bus1}(M)_{4,4}$ $\quad$ $|V_1| = 0.211\cdot pu$ $\quad$ $\arg(V_1) = -1.196\cdot deg$

$V_2 := -I_2\cdot Z_{Bus2}(M)_{4,4}$ $\quad$ $|V_2| = 0.211\cdot pu$ $\quad$ $\arg(V_2) = -1.196\cdot deg$

$V_0 := -I_0\cdot Z_{Bus0}(M)_{4,4}$ $\quad$ $|V_0| = 0.423\cdot pu$ $\quad$ $\arg(V_0) = 178.804\cdot deg$

LZO 2/22/25

$$\frac{-V_0}{2} - V_1 = 0$$

$$V_{ABC} := A_{012} \cdot \begin{pmatrix} V_0 \\ V_1 \\ V_2 \end{pmatrix} \qquad \overrightarrow{|V_{ABC}|} = \begin{pmatrix} 0 \\ 0.634 \\ 0.634 \end{pmatrix}$$

$$\arg\left(V_{ABC_1}\right) = 178.804 \cdot deg$$

$$\arg\left(V_{ABC_2}\right) = 178.804 \cdot deg$$

Very close to ATP

$$I_{ABC} := A_{012} \cdot \begin{pmatrix} I_0 \\ I_1 \\ I_2 \end{pmatrix} \qquad \overrightarrow{|I_{ABC}|} = \begin{pmatrix} 2.257 \\ 2.256 \\ 2.256 \end{pmatrix} \qquad \overrightarrow{\arg(I_{ABC})} = \begin{pmatrix} -86.316 \\ -177.191 \\ 2.809 \end{pmatrix} \cdot deg$$

SLG or LL alone (without simultaneous):

- SLG

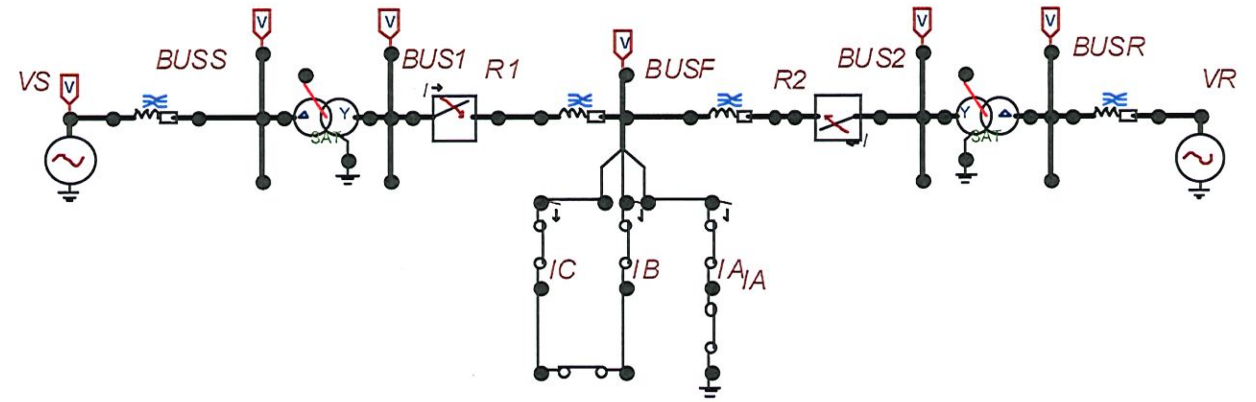
$$I_{0slg} := \frac{V_f}{\left(Z_{Bus1}(M)_{4,4} + Z_{Bus2}(M)_{4,4} + Z_{Bus0}(M)_{4,4}\right)} \qquad |I_{0slg}| = 0.752$$

$$\arg\left(I_{0slg}\right) = -86.316 \cdot deg$$

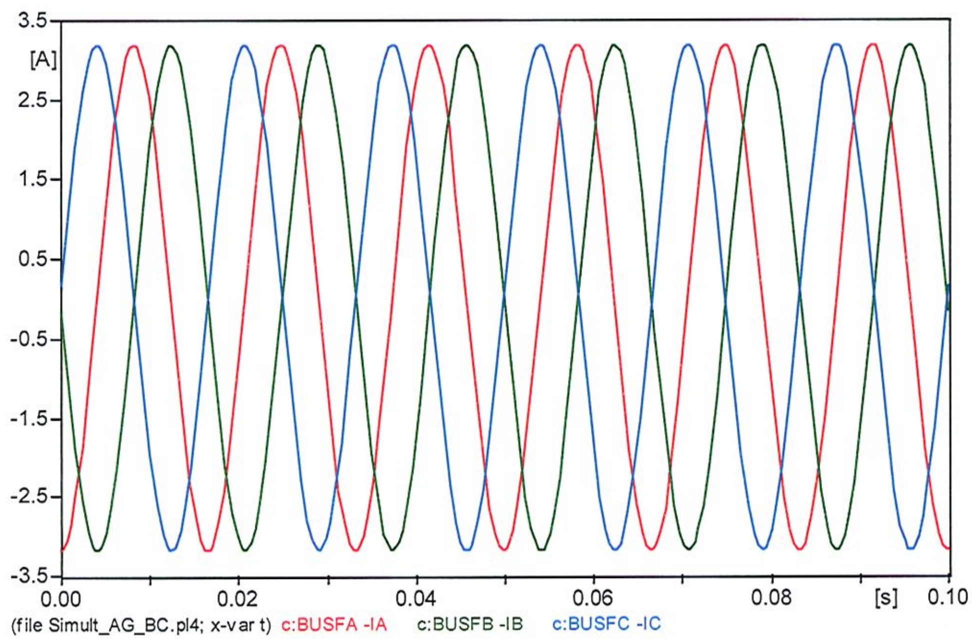
$$I_{A\_slg} := 3 \cdot I_{0slg} \qquad |I_{A\_slg}| = 2.257 \cdot pu \qquad \arg\left(I_{A\_slg}\right) = -86.316 \cdot deg$$

- Same as for simulataneous

- ***ATP System Model***



- Fault Currents (versus time):



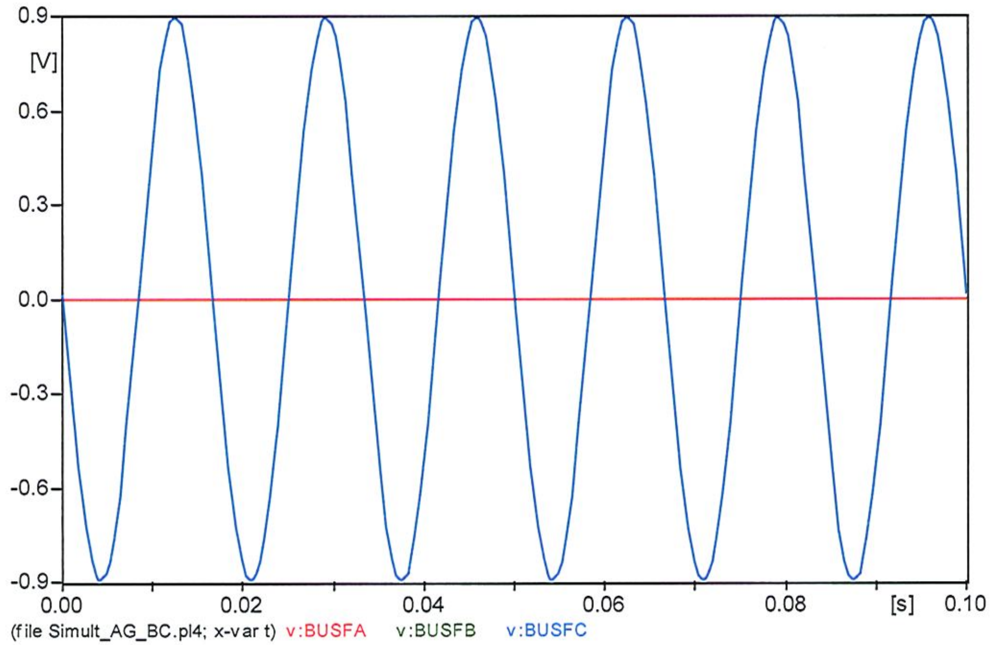
- Note that: IC = -IB

$|I_A| = 2.257A \qquad \theta_A := -86.24deg$

$|I_B| = 2.257A \qquad \theta_A := -177.1deg$

$|I_C| = 2.257A \qquad \theta_A := 2.88deg$

- Voltages at the fault point:



$|V_{AG}| = 0V$

$|V_{BG}| = 0.6339V \quad \theta_{VB} := 178.9deg$

$|V_{CG}| = 0.6339V \quad \theta_{VC} := 178.9deg$

If the faults ~~to~~ not at some location