Exam June 2010

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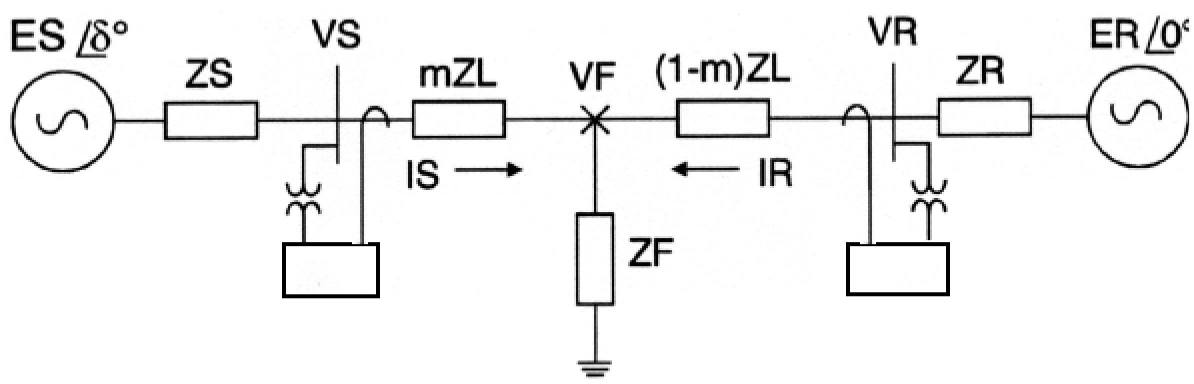
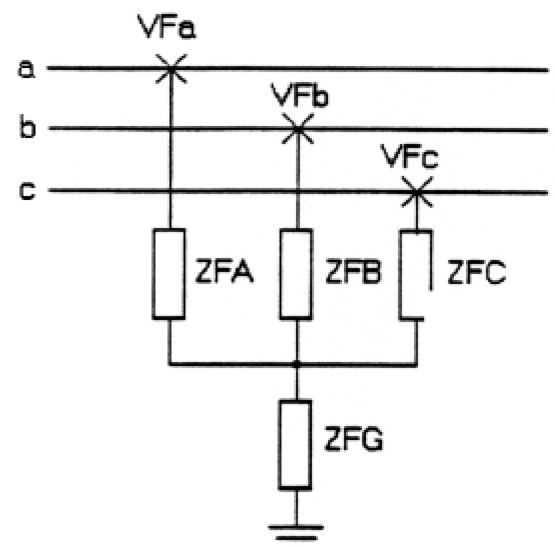
SIMPLE ONE LINE DIAGRAM



FAULT IMPEDANCE



INPUT DATA

$\delta := 1.1$ **Voltage Phase Angle**

$es := 70 \cdot e^{j \cdot \delta \cdot deg}$ **Source S Voltage** $es = 69.987 + 1.344i$

$er := 70$ **Source R Voltage**

$er := 0$

$Z1S := 4.104 + j \cdot 11.276$ **Source S Positive Sequence Impedance**

$Z0S := 25.357 + j \cdot 54.378$ **Source S Zero Sequence Impedance**

$Z1R := 0.518 + j \cdot 1.932$ **Source R Positive Sequence Impedance**

$Z0R := 3 \cdot Z1R$ **Source S Zero Sequence Impedance**

$Z1L := 1.035 + j \cdot 3.864$ **Positive Sequence Line Impedance**

$Z0L := 3 \cdot Z1L$ **Zero Sequence Line Impedance**

Fault Location

$m := .5$

Fault Impedances (for AG fault case) $INF := 10^{10}$

$ZFA := 0 + j \cdot 0$ $ZFB := INF + j \cdot 0$ $ZFC := INF + j \cdot 0$

Fault Resistance

$ZFG := 0.85 + j \cdot 0$ $ZFG := 0.1$ $ZFG := 0.4 + j \cdot 0$ $ZFG := 1.57 + j \cdot 0$ $ZFG := 10 + j \cdot 0$

CONSTANTS

$rad := 1$ $deg := \frac{\pi}{180} \cdot rad$

Operator $a := e^{j \cdot 120 \cdot deg}$ $a = -0.5 + 0.866i$

$$BAL := \begin{pmatrix} 1 \\ a^2 \\ a \end{pmatrix} \quad one := \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad zero := \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

Three phase voltages at S and R

$$ES := es \cdot BAL \qquad ES = \begin{pmatrix} 69.987 + 1.344i \\ -33.83 - 61.283i \\ -36.157 + 59.939i \end{pmatrix}$$

$$ER := er \cdot BAL \qquad ER = \begin{pmatrix} 70 \\ -35 - 60.622i \\ -35 + 60.622i \end{pmatrix}$$

CIRCUIT EQUATION

In 3-phase matrix form, the equation looks like this:

$$\begin{bmatrix} ES \\ ER \\ null \end{bmatrix} = \begin{bmatrix} ZSS & zero & one \\ zero & ZRR & one \\ -ZF & -ZF & one \end{bmatrix} \begin{bmatrix} IS \\ IR \\ VF \end{bmatrix}$$

How do we form the soure impedance ZS and ZR?

Let us consider the link between 3-phase circuit and symmetrical components

Coversion of positive sequence and zero sequence impedances to Self and Mutual impedances

$$zs(z0, z1) := \frac{2 \cdot z1 + z0}{3} \qquad zm(z0, z1) := \frac{z0 - z1}{3}$$

Conversion Matrix Format

$$Z(z0, z1) := \begin{pmatrix} zs(z0,z1) & zm(z0,z1) & zm(z0,z1) \\ zm(z0,z1) & zs(z0,z1) & zm(z0,z1) \\ zm(z0,z1) & zm(z0,z1) & zs(z0,z1) \end{pmatrix}$$

Now Conversion

$$ZS := Z(Z0S, Z1S) \qquad ZL := Z(Z0L, Z1L) \qquad ZR := Z(Z0R, Z1R)$$

$$ZS = \begin{pmatrix} 11.188 + 25.643i & 7.084 + 14.367i & 7.084 + 14.367i \\ 7.084 + 14.367i & 11.188 + 25.643i & 7.084 + 14.367i \\ 7.084 + 14.367i & 7.084 + 14.367i & 11.188 + 25.643i \end{pmatrix}$$

Source and Line Impedances to the Fault

$$ZSS := ZS + m \cdot ZL \qquad ZSS = \begin{pmatrix} 12.051 + 28.863i & 7.429 + 15.655i & 7.429 + 15.655i \\ 7.429 + 15.655i & 12.051 + 28.863i & 7.429 + 15.655i \\ 7.429 + 15.655i & 7.429 + 15.655i & 12.051 + 28.863i \end{pmatrix}$$

$$ZRR := ZR + (1 - m) \cdot ZL \qquad ZRR = \begin{pmatrix} 1.726 + 6.44i & 0.69 + 2.576i & 0.69 + 2.576i \\ 0.69 + 2.576i & 1.726 + 6.44i & 0.69 + 2.576i \\ 0.69 + 2.576i & 0.69 + 2.576i & 1.726 + 6.44i \end{pmatrix}$$

Build System Part of the Impedance Matrix

$$\begin{bmatrix} ES \\ ER \\ null \end{bmatrix} = \begin{bmatrix} ZSS & zero & one \\ zero & ZRR & one \\ -ZF & -ZF & one \end{bmatrix} \begin{bmatrix} IS \\ IR \\ VF \end{bmatrix} \qquad ES = \begin{bmatrix} ES_a \\ ES_b \\ ES_c \end{bmatrix} \quad ER = \begin{bmatrix} ER_a \\ ER_b \\ ER_c \end{bmatrix} \quad VF = \begin{bmatrix} VF_a \\ VF_b \\ VF_c \end{bmatrix} \quad IS = \begin{bmatrix} IS_a \\ IS_b \\ IS_c \end{bmatrix} \quad IR = \begin{bmatrix} IR_a \\ IR_b \\ IR_c \end{bmatrix}$$

$ZTOP := augment(augment(ZSS, zero), one)$

$$ZTOP = \begin{pmatrix} 12.051 + 28.863i & 7.429 + 15.655i & 7.429 + 15.655i & 0 & 0 & 0 & 1 & 0 & 0 \\ 7.429 + 15.655i & 12.051 + 28.863i & 7.429 + 15.655i & 0 & 0 & 0 & 0 & 1 & 0 \\ 7.429 + 15.655i & 7.429 + 15.655i & 12.051 + 28.863i & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

$ZMID := augment(augment(zero, ZRR), one)$

$$ZMID = \begin{pmatrix} 0 & 0 & 0 & 1.726 + 6.44i & 0.69 + 2.576i & 0.69 + 2.576i & 1 & 0 & 0 \\ 0 & 0 & 0 & 0.69 + 2.576i & 1.726 + 6.44i & 0.69 + 2.576i & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.69 + 2.576i & 0.69 + 2.576i & 1.726 + 6.44i & 0 & 0 & 1 \end{pmatrix}$$

$ZSYS := stack(ZTOP, ZMID)$

$$ZSYS = \begin{pmatrix} 12.051 + 28.863i & 7.429 + 15.655i & 7.429 + 15.655i & 0 & 0 & 0 & 1 & 0 & 0 \\ 7.429 + 15.655i & 12.051 + 28.863i & 7.429 + 15.655i & 0 & 0 & 0 & 0 & 1 & 0 \\ 7.429 + 15.655i & 7.429 + 15.655i & 12.051 + 28.863i & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1.726 + 6.44i & 0.69 + 2.576i & 0.69 + 2.576i & 1 & 0 & 0 \\ 0 & 0 & 0 & 0.69 + 2.576i & 1.726 + 6.44i & 0.69 + 2.576i & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.69 + 2.576i & 0.69 + 2.576i & 1.726 + 6.44i & 0 & 0 & 1 \end{pmatrix}$$

Pre-fault conditions:

$ZPRE := ZS + ZL + ZR$

$$ZPRE = \begin{pmatrix} 13.777 + 35.303i & 8.12 + 18.231i & 8.12 + 18.231i \\ 8.12 + 18.231i & 13.777 + 35.303i & 8.12 + 18.231i \\ 8.12 + 18.231i & 8.12 + 18.231i & 13.777 + 35.303i \end{pmatrix}$$

$ISPRE := ZPRE^{-1} \cdot (ES - ER)$

$$ISPRE = \begin{pmatrix} 0.071 + 0.024i \\ -0.014 - 0.073i \\ -0.056 + 0.049i \end{pmatrix}$$

$$IRPRE := ZPRE^{-1}\cdot(ER - ES)$$

$$IRPRE = \begin{pmatrix} -0.071 - 0.024i \\ 0.014 + 0.073i \\ 0.056 - 0.049i \end{pmatrix}$$

Pre_fault voltage at S end

$$VSP := ES - ZS\cdot ISPRE$$

$$VSP = \begin{pmatrix} 69.97 + 0.447i \\ -34.597 - 60.819i \\ -35.372 + 60.372i \end{pmatrix} \qquad ES = \begin{pmatrix} 69.987 + 1.344i \\ -33.83 - 61.283i \\ -36.157 + 59.939i \end{pmatrix}$$

$$VRP := ZS\cdot IRPRE - ER$$

$$VRP = \begin{pmatrix} -70.017 - 0.896i \\ 34.232 + 61.085i \\ 35.785 - 60.189i \end{pmatrix}$$

Build the voltage Vector

$$null := \begin{pmatrix} 0 & 0 & 0 \end{pmatrix}$$

$$E := stack\left(stack(ES, ER), null^T\right)$$

$$TS := augment(augment(one, zero), zero)$$

$$TR := augment(augment(zero, one), zero)$$

$$E = \begin{pmatrix} 69.987 + 1.344i \\ -33.83 - 61.283i \\ -36.157 + 59.939i \\ 70 \\ -35 - 60.622i \\ -35 + 60.622i \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

$$TS = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

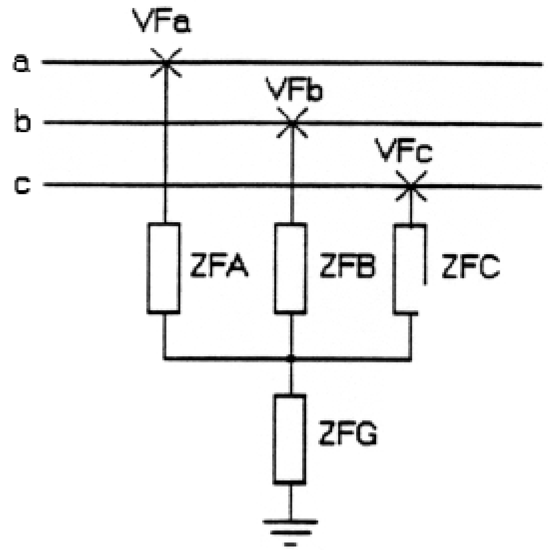
$$TR = \begin{pmatrix} 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \end{pmatrix}$$

Building Fault Part of the Impedance Matrix:

$ZFAG := ZFA + ZFG$

$ZFBG := ZFB + ZFG$

$ZFCG := ZFC + ZFG$



$ZFAG = 1.57$

$ZFBG = 1 \times 10^{10}$

$$ZF := \begin{pmatrix} ZFAG & ZFG & ZFG \\ ZFG & ZFBG & ZFG \\ ZFG & ZFG & ZFCG \end{pmatrix}$$

$$ZF = \begin{pmatrix} 1.57 & 1.57 & 1.57 \\ 1.57 & 1 \times 10^{10} & 1.57 \\ 1.57 & 1.57 & 1 \times 10^{10} \end{pmatrix}$$

$$\begin{bmatrix} ES \\ ER \\ null \end{bmatrix} = \begin{bmatrix} ZSS & zero & one \\ zero & ZRR & one \\ -ZF & -ZF & one \end{bmatrix} \begin{bmatrix} IS \\ IR \\ VF \end{bmatrix}$$

$FABCG := \mathrm{augment}(\mathrm{augment}(-ZF, -ZF), one)$

$$FABCG = \begin{pmatrix} -1.57 & -1.57 & -1.57 & -1.57 & -1.57 & -1.57 & 1 & 0 & 0 \\ -1.57 & -1 \times 10^{10} & -1.57 & -1.57 & -1 \times 10^{10} & -1.57 & 0 & 1 & 0 \\ -1.57 & -1.57 & -1 \times 10^{10} & -1.57 & -1.57 & -1 \times 10^{10} & 0 & 0 & 1 \end{pmatrix}$$

FINAL Z MATRIX

$$ZABCG := \text{stack}(ZSYS, FABCG)$$

$$ZABCG = \begin{pmatrix} 12.051+28.863i & 7.429+15.655i & 7.429+15.655i & 0 & 0 & 0 & 1 & 0 & 0 \\ 7.429+15.655i & 12.051+28.863i & 7.429+15.655i & 0 & 0 & 0 & 0 & 1 & 0 \\ 7.429+15.655i & 7.429+15.655i & 12.051+28.863i & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1.726+6.44i & 0.69+2.576i & 0.69+2.576i & 1 & 0 & 0 \\ 0 & 0 & 0 & 0.69+2.576i & 1.726+6.44i & 0.69+2.576i & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.69+2.576i & 0.69+2.576i & 1.726+6.44i & 0 & 0 & 1 \\ -1.57 & -1.57 & -1.57 & -1.57 & -1.57 & -1.57 & 1 & 0 & 0 \\ -1.57 & -1\times10^{10} & -1.57 & -1.57 & -1\times10^{10} & -1.57 & 0 & 1 & 0 \\ -1.57 & -1.57 & -1\times10^{10} & -1.57 & -1.57 & -1\times10^{10} & 0 & 0 & 1 \end{pmatrix}$$

$$YABCG := ZABCG^{-1}$$

Fault Currents:

$$IABCG := YABCG \cdot E$$

$$E = \begin{pmatrix} 69.987+1.344i \\ -33.83-61.283i \\ -36.157+59.939i \\ 70 \\ -35-60.622i \\ -35+60.622i \\ 0 \\ 0 \\ 0 \end{pmatrix} \qquad IABCG = \begin{pmatrix} 1.394-1.848i \\ -0.125+0.169i \\ -0.166+0.292i \\ 4.487-8.018i \\ 0.125-0.169i \\ 0.166-0.292i \\ 9.233-15.489i \\ -60.923-67.382i \\ -61.44+53.826i \end{pmatrix}$$

S - End Fault Currents:

$IS := TS \cdot IABCG$

$$IS = \begin{pmatrix} 1.394 - 1.848i \\ -0.125 + 0.169i \\ -0.166 + 0.292i \end{pmatrix}$$

R - End Fault Currents:

$IR := TR \cdot IABCG$

$$IR = \begin{pmatrix} 4.487 - 8.018i \\ 0.125 - 0.169i \\ 0.166 - 0.292i \end{pmatrix}$$

S - End Voltages

$VS := ES - ZS \cdot IS$

$$VS = \begin{pmatrix} 15.691 - 12.811i \\ -59.148 - 66.593i \\ -59.923 + 54.598i \end{pmatrix} \quad VSP = \begin{pmatrix} 69.97 + 0.447i \\ -34.597 - 60.819i \\ -35.372 + 60.372i \end{pmatrix}$$

R End Voltages * Additional Component for FI

$VR := (ZR \cdot IR - ER)$

$$VR = \begin{pmatrix} -39.614 + 7.741i \\ 47.962 + 64.001i \\ 48.221 - 57.225i \end{pmatrix} \quad VRP = \begin{pmatrix} -70.017 - 0.896i \\ 34.232 + 61.085i \\ 35.785 - 60.189i \end{pmatrix}$$

Line Prefault Load Currents from S Bus

$Ia := ISPRE_0$ $\quad |Ia| = 0.075$ $\quad \frac{arg(Ia)}{deg} = 18.883$ $\quad 0.32 \cdot \frac{180}{3.14} = 18.344$

$$ISPRE = \begin{pmatrix} 0.071 + 0.024i \\ -0.014 - 0.073i \\ -0.056 + 0.049i \end{pmatrix}$$

$Ib := ISPRE_1$ $\quad |Ib| = 0.075$ $\quad \frac{arg(Ib)}{deg} = -101.117$

$Ic := ISPRE_2$ $\quad |Ic| = 0.075$ $\quad \frac{arg(Ic)}{deg} = 138.883$

$$IRPRE = \begin{pmatrix} -0.071 - 0.024i \\ 0.014 + 0.073i \\ 0.056 - 0.049i \end{pmatrix}$$

Line Prefault Voltages at S Bus

$Va := VSP_0$ $\quad |Va| = 69.971$ $\quad \frac{arg(Va)}{deg} = 0.366$

$Vb := VSP_1$ $\quad |Vb| = 69.971$ $\quad \frac{arg(Vb)}{deg} = -119.634$

$Vc := VSP_2$ $\quad |Vc| = 69.971$ $\quad \frac{arg(Vc)}{deg} = 120.366$

$$VSP = \begin{pmatrix} 69.97 + 0.447i \\ -34.597 - 60.819i \\ -35.372 + 60.372i \end{pmatrix}$$

Line Fault Currents from S Bus

$Iasf := IS_0$ $\quad |Iasf| = 2.315$ $\quad \frac{arg(Iasf)}{deg} = -52.972$

$Ibsf := IS_1$ $\quad |Ibsf| = 0.21$ $\quad \frac{arg(Ibsf)}{deg} = 126.344$

$Icsf := IS_2$ $\quad |Icsf| = 0.336$ $\quad \frac{arg(Icsf)}{deg} = 119.705$

$$IS = \begin{pmatrix} 1.394 - 1.848i \\ -0.125 + 0.169i \\ -0.166 + 0.292i \end{pmatrix}$$

Line Fault Currents from R Bus

$$IR = \begin{pmatrix} 4.487 - 8.018i \\ 0.125 - 0.169i \\ 0.166 - 0.292i \end{pmatrix}$$

$Iarf := IR_0$ $\quad |Iarf| = 9.188$ $\quad \frac{arg(Iarf)}{deg} = -60.768$

$Ibrf := IR_1$ $\quad |Ibrf| = 0.21$ $\quad \frac{arg(Ibrf)}{deg} = -53.656$

$Icrf := IR_2$ $\quad |Icrf| = 0.336$ $\quad \frac{arg(Icrf)}{deg} = -60.295$

Line Fault Voltages at S Bus

$$VSP = \begin{pmatrix} 69.97 + 0.447i \\ -34.597 - 60.819i \\ -35.372 + 60.372i \end{pmatrix}$$

$Vasf := VS_0$ $\quad |Vasf| = 20.256$ $\quad \frac{arg(Vasf)}{deg} = -39.229$

$Vbsf := VS_1$ $\quad |Vbsf| = 89.068$ $\quad \frac{arg(Vbsf)}{deg} = -131.611$

$$VS = \begin{pmatrix} 15.691 - 12.811i \\ -59.148 - 66.593i \\ -59.923 + 54.598i \end{pmatrix}$$

$Vcsf := VS_2$ $\quad |Vcsf| = 81.066$ $\quad \frac{arg(Vcsf)}{deg} = 137.662$

Line Fault Voltage at R Bus

$Varf := VR_0$ $\quad |Varf| = 40.364$

$\frac{arg(Varf)}{deg} = 168.943$

$Vbrf := VR_1$ $\quad |Vbrf| = 79.978$ $\quad \frac{arg(Vbrf)}{deg} = 53.152$

$Vcrf := VR_2$ $\quad |Vcrf| = 74.833$ $\quad \frac{arg(Vcrf)}{deg} = -49.881$

$$IS = \begin{pmatrix} 1.394 - 1.848i \\ -0.125 + 0.169i \\ -0.166 + 0.292i \end{pmatrix}$$

Residual Current and Voltage Vsr, Vrr, Isr, Irr

$$IR = \begin{pmatrix} 4.487 - 8.018i \\ 0.125 - 0.169i \\ 0.166 - 0.292i \end{pmatrix}$$

$Isrf := \sum_{j=0}^{2} IS_j = 1.103 - 1.387i$ $\quad Irrf := \sum_{j=0}^{2} IR_j = 4.778 - 8.479i$

$Vsrf := \sum_{j=0}^{2} VS_j = -103.38 - 24.806i$ $\quad Vrrf := \sum_{j=0}^{2} VR_j = 56.569 + 14.516i$

$$VS = \begin{pmatrix} 15.691 - 12.811i \\ -59.148 - 66.593i \\ -59.923 + 54.598i \end{pmatrix}$$

$arg(Isrf) = -0.899$

$arg(Vsrf) = -2.906$

$arg(Irrf) = -1.058$

$arg(Vrrf) = 0.251$

$$VR = \begin{pmatrix} -39.614 + 7.741i \\ 47.962 + 64.001i \\ 48.221 - 57.225i \end{pmatrix}$$

$IRPREr := \sum_{j=0}^{2} IRPRE_j = 0$ $\quad ISPREr := \sum_{j=0}^{2} ISPRE_j = 0$

$$VRPr := \sum_{j=0}^{2} VRP_j = 7.105\times10^{-15} - 2.842i\times10^{-14}$$ $$VSPr := \sum_{j=0}^{2} VSP_j = -1.421\times10^{-14} + 2.132i\times10^{-14}$$

$$Z0s := \frac{Vsrf}{Isrf} = -25.357 - 54.378i$$ $$Z0r := \frac{Vrrf}{Irrf} = 1.554 + 5.796i$$

Wattmeteric Method ????

$S0S := Vsrf\cdot\overline{Isrf}$ $S0R := Vrrf\cdot\overline{Irrf}$

$Re(S0S) = -79.613$ $Re(S0R) = 147.195$

So How do we generate digital signals of Voltage and Current of the Simulation 4 Cycles with 7680 samples per second (128 samples per cycle in 60HZ system)?

For S side

$k := 0..511$

$delT := 0.0001302$

$$\frac{1}{delT} = 7.68\times10^{3}$$

$$\frac{7680}{60} = 128$$

$Van_k := \left|VSP_0\right|\cdot\sin\left(2\cdot\pi\cdot60\cdot k\cdot delT + arg\left(VSP_0\right)\right)$

$T1_k := k\cdot delT$

$T2_k := 512\cdot delT + k\cdot delT$

$T3_k := 1024\cdot delT + k\cdot delT$

$Vbn_k := \left|VSP_1\right|\cdot\sin\left(2\cdot\pi\cdot60\cdot k\cdot delT + arg\left(VSP_1\right)\right)$

$Vcn_k := \left|VSP_2\right|\cdot\sin\left(2\cdot\pi\cdot60\cdot k\cdot delT + arg\left(VSP_2\right)\right)$

$Vaf_k := \left|VS_0\right|\cdot\sin\left(2\cdot\pi\cdot60\cdot k\cdot delT + arg\left(VS_0\right)\right)$

$Vbf_k := \left|VS_1\right|\cdot\sin\left(2\cdot\pi\cdot60\cdot k\cdot delT + arg\left(VS_1\right)\right)$

$Vcf_k := \left|VS_2\right|\cdot\sin\left(2\cdot\pi\cdot60\cdot k\cdot delT + arg\left(VS_2\right)\right)$

$T1_k =$

0
$1.302\cdot10^{-4}$
$2.604\cdot10^{-4}$
$3.906\cdot10^{-4}$
$5.208\cdot10^{-4}$

$$Ian_k := \left|ISPRE_0\right| \cdot \sin\left(2\cdot\pi\cdot 60\cdot k\cdot delT + \arg\left(ISPRE_0\right)\right)$$

$$Ibn_k := \left|ISPRE_1\right| \cdot \sin\left(2\cdot\pi\cdot 60\cdot k\cdot delT + \arg\left(ISPRE_1\right)\right)$$

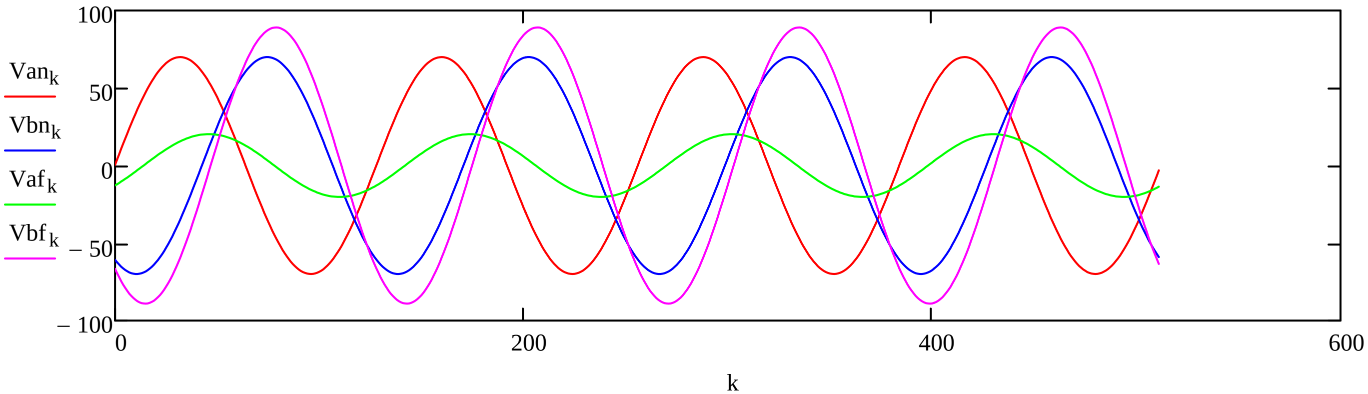
$$Icn_k := \left|ISPRE_2\right| \cdot \sin\left(2\cdot\pi\cdot 60\cdot k\cdot delT + \arg\left(ISPRE_2\right)\right)$$

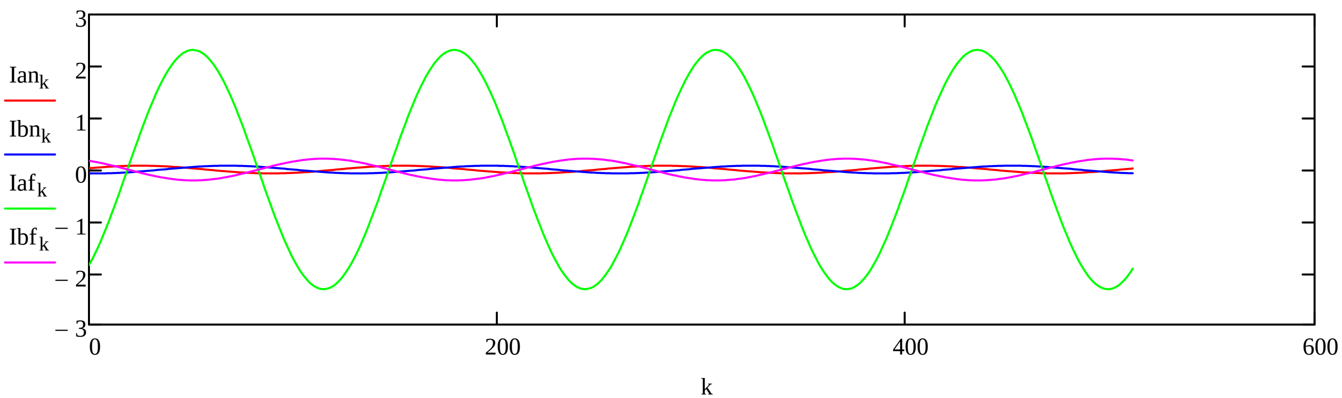
$$Iaf_k := \left|IS_0\right| \cdot \sin\left(2\cdot\pi\cdot 60\cdot k\cdot delT + \arg\left(IS_0\right)\right)$$

$$Ibf_k := \left|IS_1\right| \cdot \sin\left(2\cdot\pi\cdot 60\cdot k\cdot delT + \arg\left(IS_1\right)\right)$$

$$Icf_k := \left|IS_2\right| \cdot \sin\left(2\cdot\pi\cdot 60\cdot k\cdot delT + \arg\left(IS_2\right)\right)$$

$6.51\cdot 10^{-4}$
$7.812\cdot 10^{-4}$
$9.114\cdot 10^{-4}$
$1.042\cdot 10^{-3}$
$1.172\cdot 10^{-3}$
$1.302\cdot 10^{-3}$
$1.432\cdot 10^{-3}$
$1.562\cdot 10^{-3}$
$1.693\cdot 10^{-3}$
$1.823\cdot 10^{-3}$
...





Let us make Normal (4 cycle)+ Fault (4 cycle) +Normal (4 cycle)

$Seg1 := augment(T1, Ian, Ibn, Icn, Van, Vbn, Vcn)$

$Seg2 := augment(T2, Iaf, Ibf, Icf, Vaf, Vbf, Vcf)$

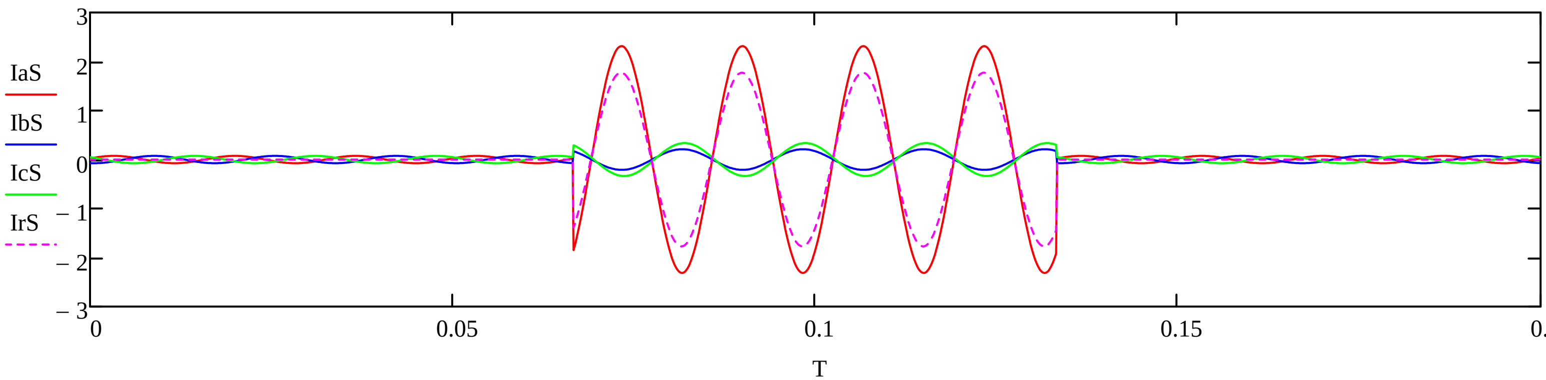
$Seg3 := augment(T3, Ian, Ibn, Icn, Van, Vbn, Vcn)$

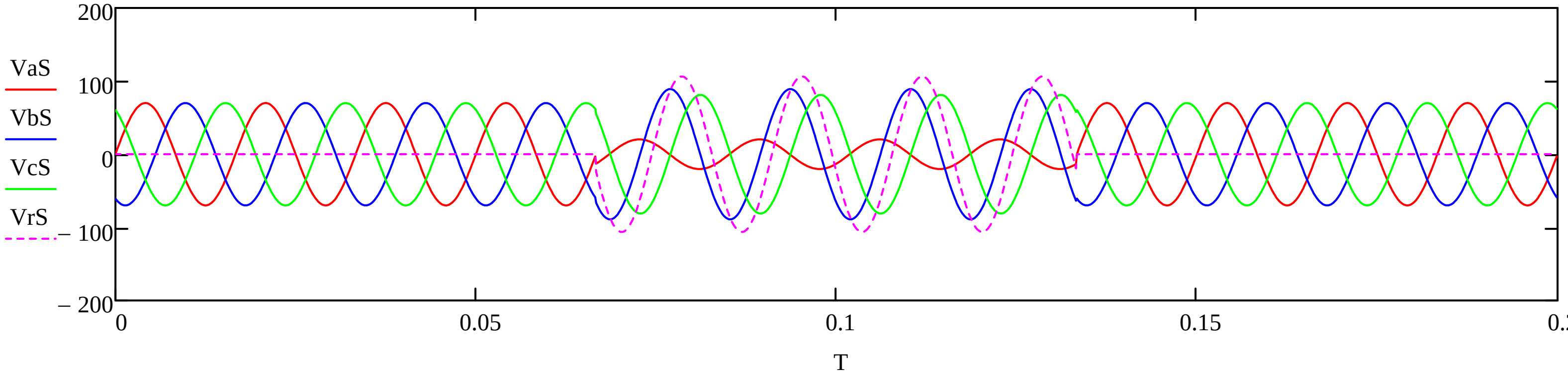
$Final := stack(Seg1, Seg2, Seg3)$

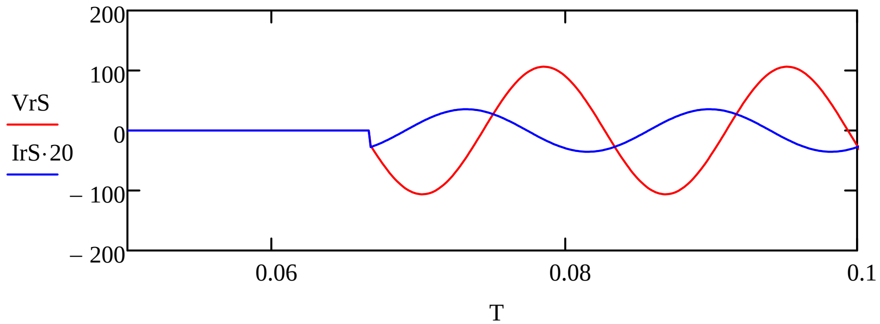
$T := Final^{\langle 0 \rangle}$ $IaS := Final^{\langle 1 \rangle}$ $IbS := Final^{\langle 2 \rangle}$ $IcS := Final^{\langle 3 \rangle}$ $VaS := Final^{\langle 4 \rangle}$ $VbS := Final^{\langle 5 \rangle}$ $VcS := Final^{\langle 6 \rangle}$

$IrS := IaS + IbS + IcS$

$VrS := VaS + VbS + VcS$







$VrS_{600} = 104.999$

$IrS_{600} = -0.488$

$dT := 0.000130208$

$\omega := 2 \cdot \pi \cdot 60$

$\omega = 376.991$

$mm := 1536$

$window := 128$

$wind := window - 1$

Now for all the calculations

$dd := 0 .. \frac{mm}{window} - 1$

$kk := 0 .. mm - window$

$k := 0 .. \frac{mm - window}{8}$

$UrS_k := \text{submatrix}(VrS, k \cdot 8, k \cdot 8 + wind, 0, 0)$

$ArS_k := \text{submatrix}(IrS, k \cdot 8, k \cdot 8 + wind, 0, 0)$

$UaS_k := \text{submatrix}(VaS, k \cdot 8, k \cdot 8 + wind, 0, 0)$

$AaS_k := \text{submatrix}(IaS, k \cdot 8, k \cdot 8 + wind, 0, 0)$

$UbS_k := \text{submatrix}(VbS, k \cdot 8, k \cdot 8 + wind, 0, 0)$

$AbS_k := \text{submatrix}(IbS, k \cdot 8, k \cdot 8 + wind, 0, 0)$

$UcS_k := \text{submatrix}(VcS, k \cdot 8, k \cdot 8 + wind, 0, 0)$

$AcS_k := \text{submatrix}(IcS, k \cdot 8, k \cdot 8 + wind, 0, 0)$

$PrS_k := \text{FFT}\left(UrS_k\right)$

$FrS_k := \text{FFT}\left(ArS_k\right)$

$CompS_k := \left(PrS_k\right)_{1,0} \cdot \overline{\left(FrS_k\right)_{1,0}}$ $CompS_{100} = -19.901 - 42.683i$ $CompS_{101} = -19.9 - 42.683i$

$WattS_k := \text{Re}\left(CompS_k\right)$

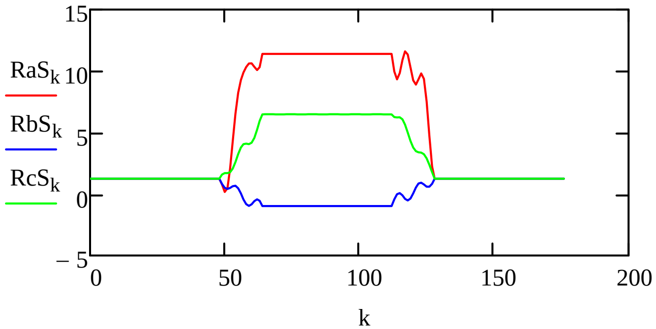
Real Current Component Method

$PaS_k := FFT(UaS_k)$ $PbS_k := FFT(UbS_k)$ $PcS_k := FFT(UcS_k)$

$FaS_k := FFT(AaS_k)$ $FbS_k := FFT(AbS_k)$ $FcS_k := FFT(AcS_k)$

$CaS_k := (PaS_k)_{1,0} \cdot \overline{(FaS_k)_{1,0}}$ $CbS_k := (PbS_k)_{1,0} \cdot \overline{(FbS_k)_{1,0}}$ $CcS_k := (PcS_k)_{1,0} \cdot \overline{(FcS_k)_{1,0}}$

$RaS_k := Re(CaS_k)$ $RbS_k := Re(CbS_k)$ $RcS_k := Re(CcS_k)$



Phase a:

$$Ima_k := \begin{bmatrix} (FaS_k)_{1,0} \\ (FbS_k)_{1,0} \\ (FcS_k)_{1,0} \end{bmatrix}$$

Z1L = 1.035 + 3.864i
Z0L = 3.105 + 11.592i

$$\alpha a := e^{\frac{2i \cdot \pi}{3}}$$

$$Am_k := \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha a & (\alpha a)^2 \\ 1 & (\alpha a)^2 & \alpha a \end{bmatrix}$$

Phase a:

$$Iaseq_k := Am_k \cdot Ima_k$$

$$I0a_k := \left(Iaseq_k\right)_0$$

$$I2a_k := \left(Iaseq_k\right)_2$$

Yang method:

$$K2 := \frac{Z0L - Z1L}{Z1L}$$

Compensated current:

Phase a:

$$Ia12_k := FaS_k + K2 \cdot I0a_k$$

$$\alpha a2_k := \arg\left(Ia12_k\right) - \arg\left(I2a_k\right)$$

Resistance and Reactance:

$X11 := Im(Z1L)$ $\quad X11 = 3.864$

$R11 := Re(Z1L)$ $\quad R11 = 1.035$

Phase Impedance:

Phase a:

$$Za1_k := \frac{PaS_k}{\left(Ia12_k\right)_{1,0}}$$

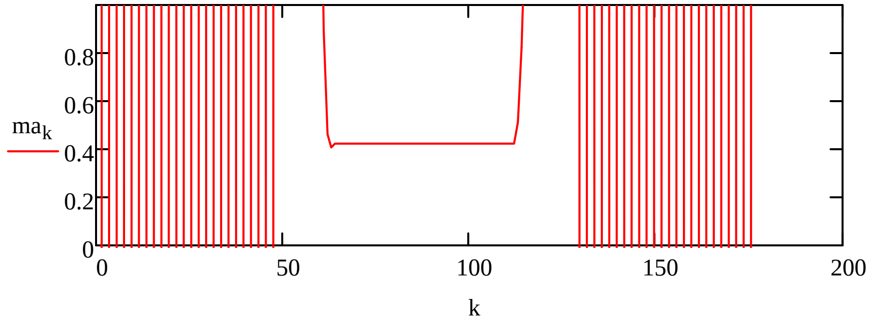
$$Xa1_k := \mathrm{Im}\left[\left(Za1_k\right)_{1,0}\right]$$

$$Ra1_k := \mathrm{Re}\left[\left(Za1_k\right)_{1,0}\right]$$

Fault Distance:

$$ma_k := \frac{\left(Xa1_k\right) + \left(Ra1_k\right)\cdot\tan\left[\left(\alpha a2_k\right)_{1,0}\right]}{X11 + R11\cdot\tan\left[\left(\alpha a2_k\right)_{1,0}\right]}$$

$m = 0.5$



$ma_{60} = 1.905$

$ma_{40} = 69.834$

$ma_{70} = 0.424$

$ma_{100} = 0.423$

$ma_{110} = 0.424$

Results and Discussion Part1:

When changing the m value (place of the fault) at start of the file ma is changing in same relation. However, ma values seem to come more exact when m is bigger.

m=0.25	ma=0.217
m=0.45	ma=0.41
m=0.5	ma=0.459
m=0.75	ma=0.695
m=0.9	ma=0.83

Fault resistance ZFG was changed and fault place m was constant (m=0.5). If the change of resistance is minor, algorithm works. If value of ZFG increase much, algorithm stops working.

m=0.5

ZFG=0.4+j0	ma=0.48
ZFG= 0.85+j0	ma=0.458
ZFG=1.57+j0	ma=0.423
ZFG= 10+j0	ma=7.378*10^-3