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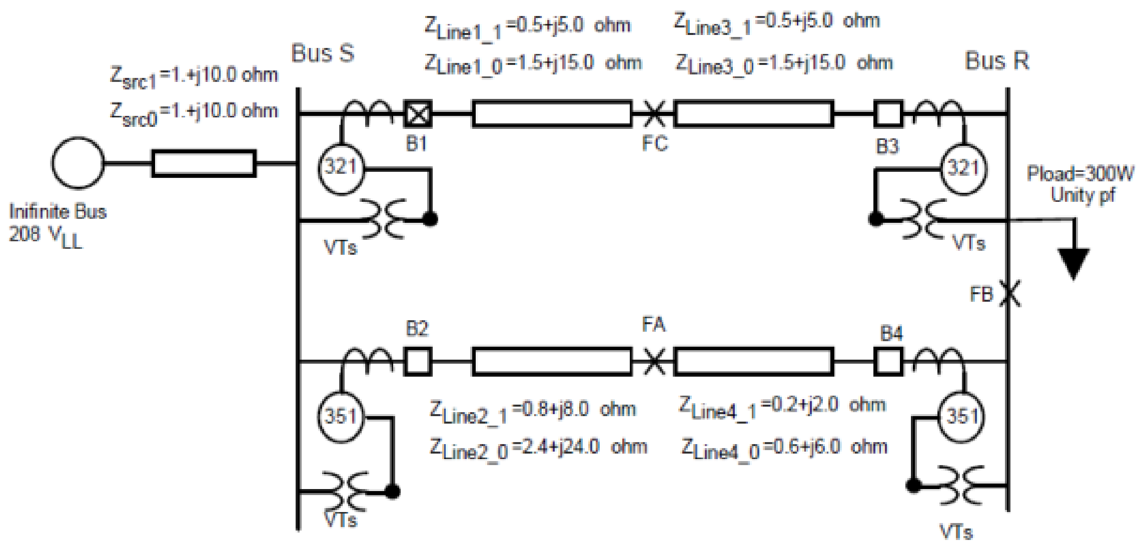
Lab 1 ECE525



Before the Lab

1. Calculate load current and potential fault currents and voltages seen at the relay at B2 for faults placed at the boundaries of zone 1 (80% of the way from BusS to BusR) and zone 2 (150% of the impedance of Line2 + Line4) to determine the relay settings.

   - FA ia at 80% of the line.
   - FB ia at 100% of the line.
   - FC ia at 150% of the line.

Note: For our purposes, all electrical characteristics related to the protective relays and breakers will be ignored.

In [49]:

```
# Import the Necessary Libraries
###########################################
import numpy as np
from scipy.optimize import fsolve
import cmath as c
import eepower as eep
from eepower import u, m, k, M
```

In [50]:

```python
# Define All System Components
##########################################
Vsrc_ll = 208 #V angle 0
Zsrc1 = 1+10j
Zsrc0 = 1+10j
Zline1_1 = 0.5+5j
Zline1_0 = 1.5+15j
Zline2_1 = 0.8+8j
Zline2_0 = 2.4+24j
Zline3_1 = 0.5+5j
Zline3_0 = 1.5+15j
Zline4_1 = 0.2+2j
Zline4_0 = 0.6+6j
Pload_3phs = 300
PF = 1.0
```

In [96]:

```python
# Calculate (pre-fault) Load Current
###########################################

# Find total Positive-Sequence Impedance
Zp_eq = Zsrc1 + Zline2_1 + Zline4_1
print("Total Pos-Seq Z:",Zp_eq,"ohms")

# Constant Power Load will vary current draw to meet voltage characteristics
# Luckily, we can model it as a resistor since it's unity PF.
Vsrc_ln = eep.phaseline(VLL = Vsrc_ll)
eep.cprint(Vsrc_ln,"Volts","Line-Neutral Source Voltage")

# Define Functions
I1 = lambda VL: abs((Vsrc_ln - VL) / Zp_eq)
I2 = lambda VL: Pload_3phs / (3*VL)
loadvolt = lambda VL: I1(VL) - I2(VL)

# Use Numerical Solver to Calculate Load Voltage
VL = fsolve(loadvolt, 50)
print("Load Voltage Magnitude (L-N):",VL[0],"Volts")

# Use Function to determine the pre-fault load current
Iload = I1(VL)[0]
print("Load Current Magnitude:",Iload,"Amps")

# Since no reference angle given on Vsrc, and load declared as unity-PF,
# we can "set" the load voltage and current to angle-0-degrees

# Find Load Current from Source
Vz = Iload * Zp_eq
IL = Iload * eep.phasor(1,-np.degrees(c.phase(Vz)))
Iload = [IL, IL * eep.a**2, IL * eep.a]
eep.cprint(Iload,"Amps","Load Current:")

# Find Pre-Fault Voltage at Relay and Breaker 2
Vpre = abs(Vsrc_ln) - IL * Zsrc1
eep.cprint(Vpre,"Volts","Pre-Fault Voltage at Bus S:")

# Find Pre-Fault Approximate Load Impedance
Zload = VL/I1(VL)[0]
print("Load Resistance:",Zload[0],"ohms")
```

```
Total Pos-Seq Z: (2+20j) ohms
Line-Neutral Source Voltage 120.089 ∠ 0.0° Volts
Load Voltage Magnitude (L-N): 99.98636346596534 Volts
Load Current Magnitude: 1.0001363839383888 Amps
[['Load Current: 1.0 ∠ -84.289° Amps']
 ['Load Current: 1.0 ∠ 155.711° Amps']
 ['Load Current: 1.0 ∠ 35.711° Amps']]
Pre-Fault Voltage at Bus S: 110.038 ∠ 0.0° Volts
Load Resistance: 99.97272879148129 ohms
```

In [60]:

```python
# Calculate the Sequence Impedances
##########################################

# Pos/Neg and Zero Sequence for FA
Zseq1_A = Zsrc1 + Zline2_1
Zseq0_A = Zsrc0 + Zline2_0
ZFA = [Zseq0_A, Zseq1_A, Zseq1_A]

# Pos/Neg and Zero Sequence for FB
Zseq1_B = Zp_eq
Zseq0_B = Zsrc0 + Zline2_0 + Zline4_0
ZFB = [Zseq0_B, Zseq1_B, Zseq1_B]

# Pos/Neg and Zero Sequence for FC
Zseq1_C = Zsrc1 + Zline2_1 + Zline4_1 + Zline3_1
Zseq0_C = Zsrc0 + Zline2_0 + Zline4_0 + Zline3_0
ZFC = [Zseq0_C, Zseq1_C, Zseq1_C]
```

In [90]:

```python
# Calculate the Total Currents
##########################################
# Total = Fault + Load

# Single Line to Ground
print("SLG Results:")
IFA_slg = eep.fault.phs1g(Vsrc_ln,ZFA,sequence=False)
eep.cprint(IFA_slg + Iload,"Amps","IFA-SLG")
IFB_slg = eep.fault.phs1g(Vsrc_ln,ZFB,sequence=False)
eep.cprint(IFB_slg + Iload,"Amps","IFB-SLG")
IFC_slg = eep.fault.phs1g(Vsrc_ln,ZFC,sequence=False)
eep.cprint(IFC_slg + Iload,"Amps","IFC-SLG")
print()

# Double Line to Ground
print("DLG Results:")
IFA_dlg = eep.fault.phs2g(Vsrc_ln,ZFA,sequence=False)
eep.cprint(IFA_dlg + Iload,"Amps","IFA-DLG")
IFB_dlg = eep.fault.phs2g(Vsrc_ln,ZFB,sequence=False)
eep.cprint(IFB_dlg + Iload,"Amps","IFB-DLG")
IFC_dlg = eep.fault.phs2g(Vsrc_ln,ZFC,sequence=False)
eep.cprint(IFC_dlg + Iload,"Amps","IFC-DLG")
print()

# Double Line
print("Line-to-Line Results:")
IFA_dl = eep.fault.phs2(Vsrc_ln,ZFA,sequence=False)
eep.cprint(IFA_dl + Iload,"Amps","IFA-DL")
IFB_dl = eep.fault.phs2(Vsrc_ln,ZFB,sequence=False)
eep.cprint(IFB_dl + Iload,"Amps","IFB-DL")
IFC_dl = eep.fault.phs2(Vsrc_ln,ZFC,sequence=False)
eep.cprint(IFC_dl + Iload,"Amps","IFC-DL")
print()

# Double Line
print("Bolted (3-Phase) Results:")
IFA_3 = eep.fault.phs3(Vsrc_ln,ZFA,sequence=False)
eep.cprint(IFA_3 + Iload,"Amps","IFA-Bolted")
IFB_3 = eep.fault.phs3(Vsrc_ln,ZFB,sequence=False)
eep.cprint(IFB_3 + Iload,"Amps","IFB-Bolted")
IFC_3 = eep.fault.phs3(Vsrc_ln,ZFC,sequence=False)
eep.cprint(IFC_3 + Iload,"Amps","IFC-Bolted")
```

```
SLG Results:
[['IFA-SLG 6.121 ∠ -84.289° Amps']
 ['IFA-SLG 1.0 ∠ 155.711° Amps']
 ['IFA-SLG 1.0 ∠ 35.711° Amps']]
[['IFB-SLG 5.481 ∠ -84.289° Amps']
 ['IFB-SLG 1.0 ∠ 155.711° Amps']
 ['IFB-SLG 1.0 ∠ 35.711° Amps']]
[['IFC-SLG 4.414 ∠ -84.289° Amps']
 ['IFC-SLG 1.0 ∠ 155.711° Amps']
 ['IFC-SLG 1.0 ∠ 35.711° Amps']]

DLG Results:
[['IFA-DLG 1.0 ∠ -84.289° Amps']
 ['IFA-DLG 7.102 ∠ 164.372° Amps']
```

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 ['IFA-DLG 7.102 ∠ 27.049° Amps']]
[['IFB-DLG 1.0 ∠ -84.289° Amps']
 ['IFB-DLG 6.461 ∠ 164.928° Amps']
 ['IFB-DLG 6.461 ∠ 26.494° Amps']]
[['IFC-DLG 1.0 ∠ -84.289° Amps']
 ['IFC-DLG 5.329 ∠ 165.651° Amps']
 ['IFC-DLG 5.329 ∠ 25.77° Amps']]

Line-to-Line Results:
[['IFA-DL 1.0 ∠ -84.289° Amps']
 ['IFA-DL 6.634 ∠ -178.612° Amps']
 ['IFA-DL 6.634 ∠ 10.034° Amps']]
[['IFB-DL 1.0 ∠ -84.289° Amps']
 ['IFB-DL 6.061 ∠ -179.022° Amps']
 ['IFB-DL 6.061 ∠ 10.443° Amps']]
[['IFC-DL 1.0 ∠ -84.289° Amps']
 ['IFC-DL 5.03 ∠ -179.995° Amps']
 ['IFC-DL 5.03 ∠ 11.416° Amps']]

Bolted (3-Phase) Results:
[['IFA-Bolted 7.639 ∠ -84.289° Amps']
 ['IFA-Bolted 7.639 ∠ 155.711° Amps']
 ['IFA-Bolted 7.639 ∠ 35.711° Amps']]
[['IFB-Bolted 6.975 ∠ -84.289° Amps']
 ['IFB-Bolted 6.975 ∠ 155.711° Amps']
 ['IFB-Bolted 6.975 ∠ 35.711° Amps']]
[['IFC-Bolted 5.78 ∠ -84.289° Amps']
 ['IFC-Bolted 5.78 ∠ 155.711° Amps']
 ['IFC-Bolted 5.78 ∠ 35.711° Amps']]
```

In [121]:

```
# Calculate the Voltage at Bus S
###########################################

# Make Vsrc Matrix
Vsrc = [Vsrc_ln, Vsrc_ln*eep.a**2, Vsrc_ln*eep.a]

# Single Line to Ground Fault
print("SLG Results:")
eep.cprint(Vsrc - ((IFA_slg + Iload) * Zsrc1),"Volts","VFA-SLG:")
eep.cprint(Vsrc - ((IFB_slg + Iload) * Zsrc1),"Volts","VFB-SLG:")
eep.cprint(Vsrc - ((IFC_slg + Iload) * Zsrc1),"Volts","VFC-SLG:")
print()

# Double Line to Ground Fault
print("DLG Results:")
eep.cprint(Vsrc - ((IFA_dlg + Iload) * Zsrc1),"Volts","VFA-DLG:")
eep.cprint(Vsrc - ((IFB_dlg + Iload) * Zsrc1),"Volts","VFB-DLG:")
eep.cprint(Vsrc - ((IFC_dlg + Iload) * Zsrc1),"Volts","VFC-DLG:")
print()

# Double Line Fault
print("Line-to-Line Results:")
eep.cprint(Vsrc - ((IFA_dl + Iload) * Zsrc1),"Volts","VFA-DL:")
eep.cprint(Vsrc - ((IFB_dl + Iload) * Zsrc1),"Volts","VFB-DL:")
eep.cprint(Vsrc - ((IFC_dl + Iload) * Zsrc1),"Volts","VFC-DL:")
print()

# Bolted Fault
print("Bolted (3-Phase) Results:")
eep.cprint(Vsrc - ((IFA_3 + Iload) * Zsrc1),"Volts","VFA-Bolted:")
eep.cprint(Vsrc - ((IFB_3 + Iload) * Zsrc1),"Volts","VFB-Bolted:")
eep.cprint(Vsrc - ((IFC_3 + Iload) * Zsrc1),"Volts","VFC-Bolted:")
```

```
SLG Results:
[['VFA-SLG: 58.571 ∠ 0.0° Volts']
 ['VFA-SLG: 110.038 ∠ -120.0° Volts']
 ['VFA-SLG: 110.038 ∠ 120.0° Volts']]
[['VFB-SLG: 65.004 ∠ 0.0° Volts']
 ['VFB-SLG: 110.038 ∠ -120.0° Volts']
 ['VFB-SLG: 110.038 ∠ 120.0° Volts']]
[['VFC-SLG: 75.727 ∠ 0.0° Volts']
 ['VFC-SLG: 110.038 ∠ -120.0° Volts']
 ['VFC-SLG: 110.038 ∠ 120.0° Volts']]

DLG Results:
[['VFA-DLG: 110.038 ∠ 0.0° Volts']
 ['VFA-DLG: 50.681 ∠ -132.245° Volts']
 ['VFA-DLG: 50.681 ∠ 132.245° Volts']]
[['VFB-DLG: 110.038 ∠ 0.0° Volts']
 ['VFB-DLG: 56.955 ∠ -130.521° Volts']
 ['VFB-DLG: 56.955 ∠ 130.521° Volts']]
[['VFC-DLG: 110.038 ∠ 0.0° Volts']
 ['VFC-DLG: 67.971 ∠ -127.817° Volts']
 ['VFC-DLG: 67.971 ∠ 127.817° Volts']]

Line-to-Line Results:
[['VFA-DL: 110.038 ∠ 0.0° Volts']
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 ['VFA-DL: 66.593 ∠ -145.71° Volts']
 ['VFA-DL: 66.593 ∠ 145.71° Volts']]
[['VFB-DL: 110.038 ∠ 0.0° Volts']
 ['VFB-DL: 70.011 ∠ -141.8° Volts']
 ['VFB-DL: 70.011 ∠ 141.8° Volts']]
[['VFC-DL: 110.038 ∠ 0.0° Volts']
 ['VFC-DL: 76.878 ∠ -135.697° Volts']
 ['VFC-DL: 76.878 ∠ 135.697° Volts']]

Bolted (3-Phase) Results:
[['VFA-Bolted: 43.322 ∠ 0.0° Volts']
 ['VFA-Bolted: 43.322 ∠ -120.0° Volts']
 ['VFA-Bolted: 43.322 ∠ 120.0° Volts']]
[['VFB-Bolted: 49.993 ∠ 0.0° Volts']
 ['VFB-Bolted: 49.993 ∠ -120.0° Volts']
 ['VFB-Bolted: 49.993 ∠ 120.0° Volts']]
[['VFC-Bolted: 62.002 ∠ 0.0° Volts']
 ['VFC-Bolted: 62.002 ∠ -120.0° Volts']
 ['VFC-Bolted: 62.002 ∠ 120.0° Volts']]
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In [ ]:

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In [ ]:

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