Joe Stanley

ECE 524 - FINAL EXAM

In [16]:

```
# Import Libraries
import numpy as np
import matplotlib.pyplot as plt
import eepower as eep
from eepower import p,n,u,m,k,M

# Define Plotting Function
def atpdataplot(fname,title="",labels=None,xlim=None):
    # Condition Inputs
    if fname[-4:] != ".ADF":
        if fname[-4:] != ".adf":
            fname += ".ADF"
        else:
            fname = fname[:-4] + ".ADF"
    # Load Data from File
    data = np.genfromtxt(fname,delimiter='\t',skip_header=2,unpack=True)
    t_arr = data[0]
    # Plot Data
    for i in range(1,len(data)-1):
        d_set = data[i]
        if labels != None:
            try:
                d_name = labels[i-1]
            except:
                d_name = "Entry "+str(i)
            plt.plot(t_arr,d_set,label=d_name)
        else:
            plt.plot(t_arr,d_set)
    plt.title(title)
    if labels != None:
        plt.legend()
    if xlim != None:
        plt.xlim(xlim)
    plt.show()
```

Problem 1

25MI Section

```
KARD  3  3  4  4  5  5  6  6  7  7  8  8  9  9 10 10 11 11
KARG  1 10  2 11  3 12  4 13  5 14  6 15  7 16  8 17  9 18
KBEG  3  9  3  9  3  9  3  9  3  9  3  9  3  9  3  9  3  9
KEND  8 14  8 14  8 14  8 14  8 14  8 14  8 14  8 14  8 14
KTEX  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
/BRANCH
VINTAGE, 1
-1IN___AOUT__A             8.46916E-01 9.86461E+02 9.11449E+04-1.25000E+
01 1  9
-2IN___BOUT__B             4.90624E-02 4.90748E+02 1.56156E+05-1.25000E+
01 1  9
-3IN___COUT__C             4.49365E-02 3.66942E+02 1.73129E+05-1.25000E+
01 1  9
-4IN___DOUT__D             3.66310E-02 2.55102E+02 1.81007E+05-1.25000E+
01 1  9
-5IN___EOUT__E             6.03907E-02 2.57172E+02 1.83588E+05-1.25000E+
01 1  9
-6IN___FOUT__F             4.11214E-02 2.15286E+02 1.83313E+05-1.25000E+
01 1  9
-7IN___GOUT__G             3.20448E-02 2.10301E+02 1.83427E+05-1.25000E+
01 1  9
-8IN___HOUT__H             3.23347E-02 1.85518E+02 1.84521E+05-1.25000E+
01 1  9
-9IN___IOUT__I             3.26577E-02 1.89758E+02 1.84403E+05-1.25000E+
01 1  9
VINTAGE, 0
  0.25459016 -0.28578499  0.08062086  0.11335363  0.49452695  0.65633465
  0.05210785 -0.02548649  0.01757359
 -0.00214746 -0.00163171  0.04145063 -0.13972595 -0.04923833  0.06204167
 -0.16262080  0.06901223  0.09035807
  0.25181870 -0.33142966  0.25779302 -0.09576600 -0.78042732  0.20342169
 -0.05807565  0.02129701  0.04525270
 -0.00467529 -0.00052754  0.03048257 -0.05439639 -0.00967506 -0.10185594
 -0.06059491  0.03323815  0.02125391
  0.29453910 -0.41196398  0.43833080 -0.26811116  0.36849689 -0.49857718
 -0.10370434  0.02931978  0.01111147
 -0.01136341  0.02031202 -0.03208499  0.10734132  0.04946835 -0.07362000
  0.10240355 -0.03614565 -0.05935866
  0.37037324  0.09834052 -0.43925563 -0.37782413 -0.00147644  0.08476747
 -0.47998870 -0.43868258 -0.21246403
  0.00599144 -0.01145508 -0.01593004  0.03325380 -0.00237691 -0.09535404
 -0.10177552  0.01062066  0.12740576
  0.34611560 -0.09134549 -0.46304661  0.13528527 -0.00290004 -0.14842598
 -0.21524836  0.51099006  0.51914960
  0.00613417 -0.01411720 -0.01094295  0.06616933 -0.00335852 -0.15321679
  0.13705067  0.11694772 -0.12614246
  0.36417560 -0.27418836 -0.30661142  0.51049916 -0.07210733 -0.32030721
  0.45981282 -0.24912649 -0.35296533
  0.00447504 -0.01467881  0.02502189  0.02133822  0.01961856  0.29737772
```

```
 0.08525134 -0.15550527 -0.01089246
 0.39004670  0.52025682  0.43053543  0.47432008 -0.00247036 -0.03683601
-0.38423703  0.18381415 -0.26805925
-0.00584214 -0.00178966 -0.01321173  0.02998290  0.00131018 -0.01076907
 0.04740431 -0.01199024 -0.04511730
 0.33588765  0.40756564  0.19406895 -0.03123462 -0.00054071 -0.00190396
 0.27869281 -0.45116311  0.56514007
 0.00121724  0.01022184  0.00892381 -0.00403456 -0.00039310  0.03272859
-0.04512903  0.09053997  0.08866530
 0.36078240  0.32820866 -0.07474509 -0.46257608  0.00034969  0.05746154
 0.43398443  0.42267311 -0.32395809
 0.00400714  0.00242172  0.00001289 -0.06035449 -0.00096611  0.03095573
-0.00786206 -0.11377587 -0.08826399
EOF
ARG, IN___A, IN___B, IN___C, IN___D, IN___E, IN___F, IN___G, IN___H, IN_
__I
ARG, OUT__A, OUT__B, OUT__C, OUT__D, OUT__E, OUT__F, OUT__G, OUT__H, OUT
__I
```

12.5MI Section

```
KARD  3  3  4  4  5  5  6  6  7  7  8  8  9  9 10 10 11 11
KARG  1 10  2 11  3 12  4 13  5 14  6 15  7 16  8 17  9 18
KBEG  3  9  3  9  3  9  3  9  3  9  3  9  3  9  3  9  3  9
KEND  8 14  8 14  8 14  8 14  8 14  8 14  8 14  8 14  8 14
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/BRANCH
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01 1  9
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-8IN___HOUT__H             3.23347E-02 1.85518E+02 1.84521E+05-1.25000E+
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  0.05210785 -0.02548649  0.01757359
 -0.00214746 -0.00163171  0.04145063 -0.13972595 -0.04923833  0.06204167
 -0.16262080  0.06901223  0.09035807
  0.25181870 -0.33142966  0.25779302 -0.09576600 -0.78042732  0.20342169
 -0.05807565  0.02129701  0.04525270
 -0.00467529 -0.00052754  0.03048257 -0.05439639 -0.00967506 -0.10185594
 -0.06059491  0.03323815  0.02125391
  0.29453910 -0.41196398  0.43833080 -0.26811116  0.36849689 -0.49857718
 -0.10370434  0.02931978  0.01111147
 -0.01136341  0.02031202 -0.03208499  0.10734132  0.04946835 -0.07362000
  0.10240355 -0.03614565 -0.05935866
  0.37037324  0.09834052 -0.43925563 -0.37782413 -0.00147644  0.08476747
 -0.47998870 -0.43868258 -0.21246403
  0.00599144 -0.01145508 -0.01593004  0.03325380 -0.00237691 -0.09535404
 -0.10177552  0.01062066  0.12740576
  0.34611560 -0.09134549 -0.46304661  0.13528527 -0.00290004 -0.14842598
 -0.21524836  0.51099006  0.51914960
  0.00613417 -0.01411720 -0.01094295  0.06616933 -0.00335852 -0.15321679
  0.13705067  0.11694772 -0.12614246
  0.36417560 -0.27418836 -0.30661142  0.51049916 -0.07210733 -0.32030721
  0.45981282 -0.24912649 -0.35296533
  0.00447504 -0.01467881  0.02502189  0.02133822  0.01961856  0.29737772
```
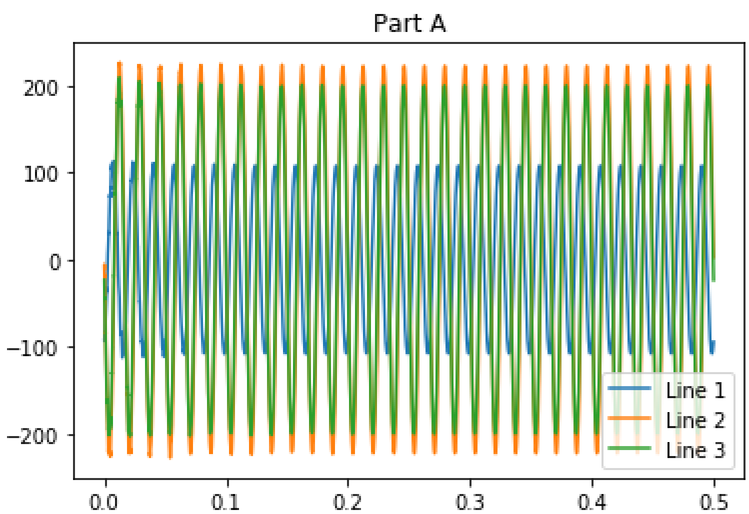
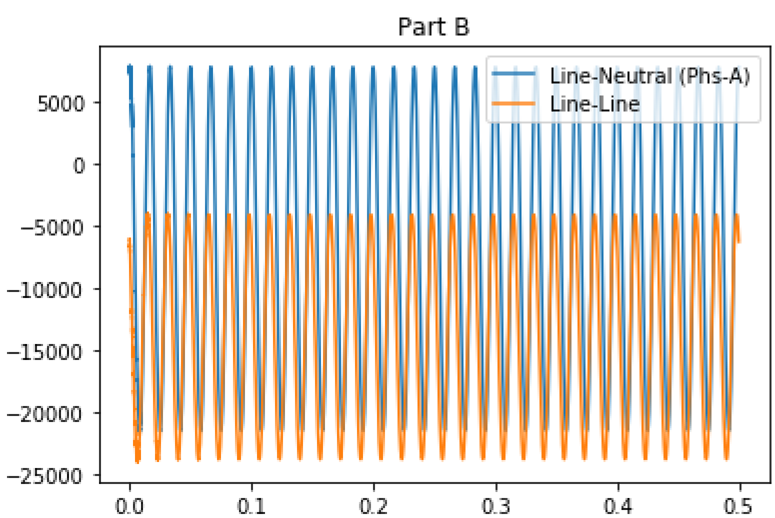

```
 0.08525134 -0.15550527 -0.01089246
 0.39004670  0.52025682  0.43053543  0.47432008 -0.00247036 -0.03683601
-0.38423703  0.18381415 -0.26805925
-0.00584214 -0.00178966 -0.01321173  0.02998290  0.00131018 -0.01076907
 0.04740431 -0.01199024 -0.04511730
 0.33588765  0.40756564  0.19406895 -0.03123462 -0.00054071 -0.00190396
 0.27869281 -0.45116311  0.56514007
 0.00121724  0.01022184  0.00892381 -0.00403456 -0.00039310  0.03272859
-0.04512903  0.09053997  0.08866530
 0.36078240  0.32820866 -0.07474509 -0.46257608  0.00034969  0.05746154
 0.43398443  0.42267311 -0.32395809
 0.00400714  0.00242172  0.00001289 -0.06035449 -0.00096611  0.03095573
-0.00786206 -0.11377587 -0.08826399
EOF
ARG, IN___A, IN___B, IN___C, IN___D, IN___E, IN___F, IN___G, IN___H, IN_
__I
ARG, OUT__A, OUT__B, OUT__C, OUT__D, OUT__E, OUT__F, OUT__G, OUT__H, OUT
__I
```

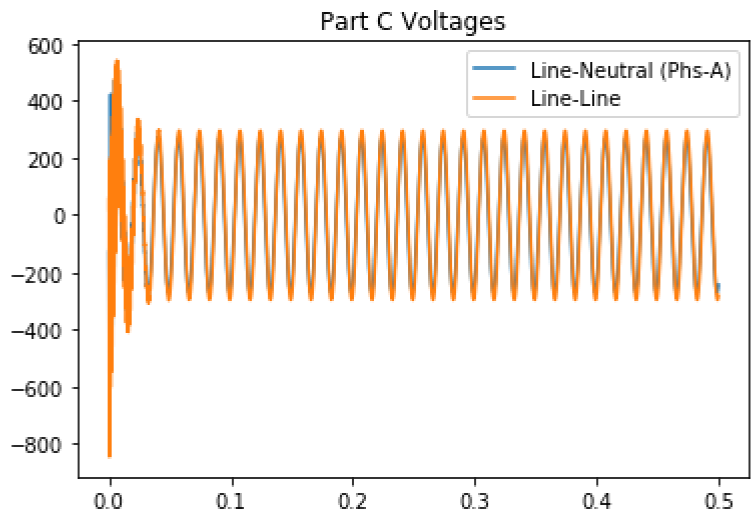
In [21]:

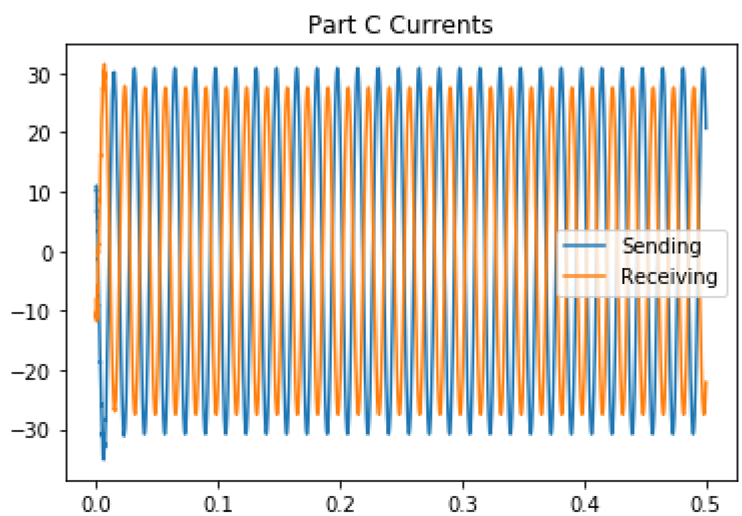
```
# Calculations
R1 = eep.phaseline(VLL=345*k)/440
print("Load Resistance (Y-Config):",R1,"Ω")
R2 = eep.phaseline(VLL=500*k)/830
print("Load Resistance (Y-Config):",R2,"Ω")

# Plot For Part A
atpdataplot("1_A",title="Part A",labels=["Line 1","Line 2","Line 3"],xlim=No

# Plot For Part B
atpdataplot("1_B",title="Part B",labels=["Line-Neutral (Phs-A)","Line-Line"]

# Plot For Part C
atpdataplot("1_C1",title="Part C Voltages",labels=["Line-Neutral (Phs-A)","L
atpdataplot("1_C2",title="Part C Currents",labels=["Sending","Receiving"],xl
```

```
Load Resistance (Y-Config): 452.69509743277484 Ω
Load Resistance (Y-Config): 347.80136698170224 Ω
```







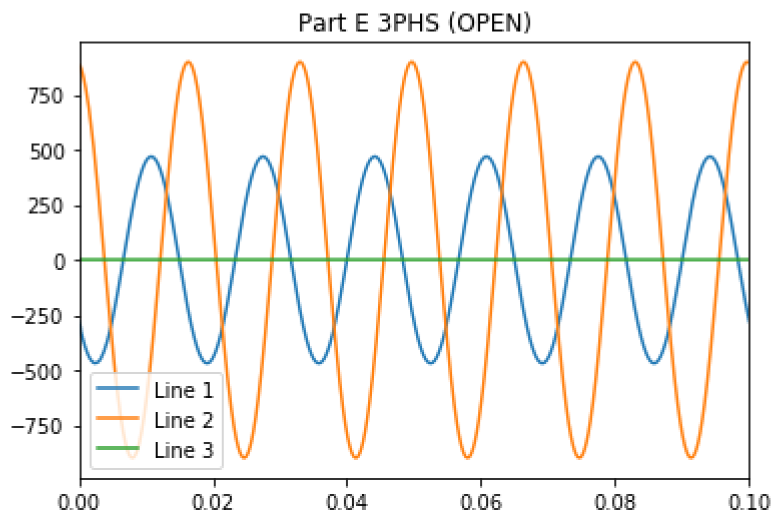


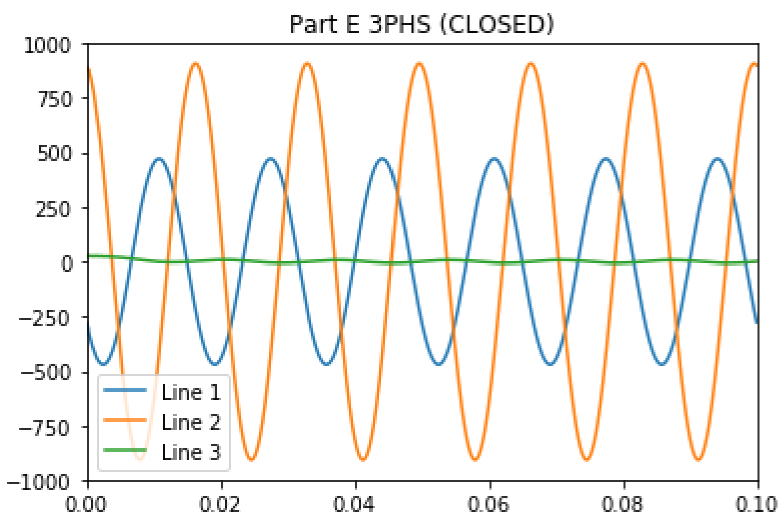
Part D Discussion:

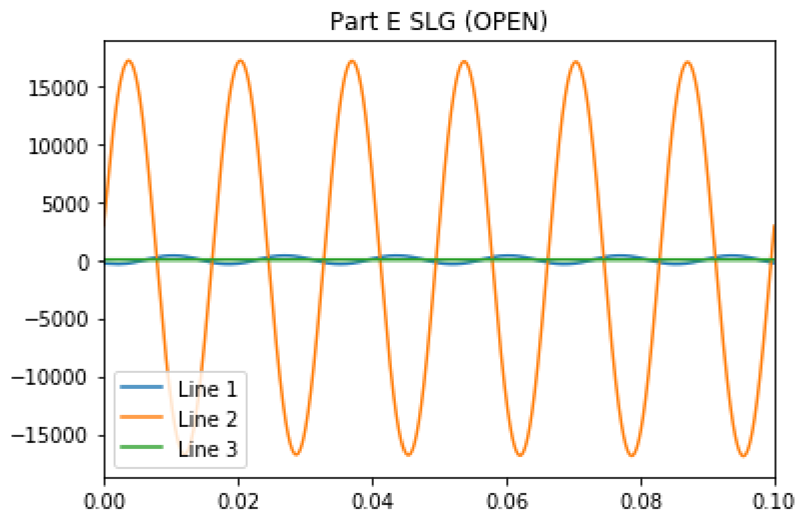
As the differences appear in the results of the system being modeled, it appears that the coupling is largely inductive. I make this deduction based on the fact that without any complete circuit path, the voltages in part B are very large as compared to the grounded case evaluated in part C. In part B, we see very high voltages that are induced entirely by the adjacent lines. In part C, we see the significantly lower voltages due to the ground and phase return paths.

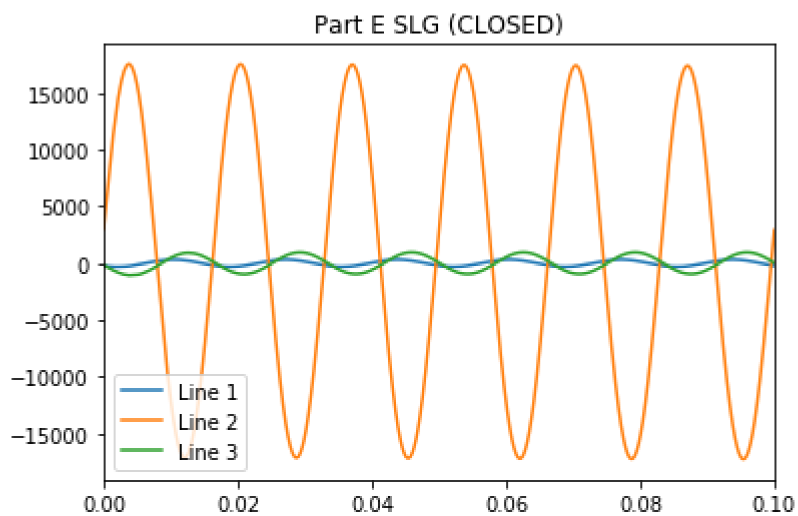
In [22]:

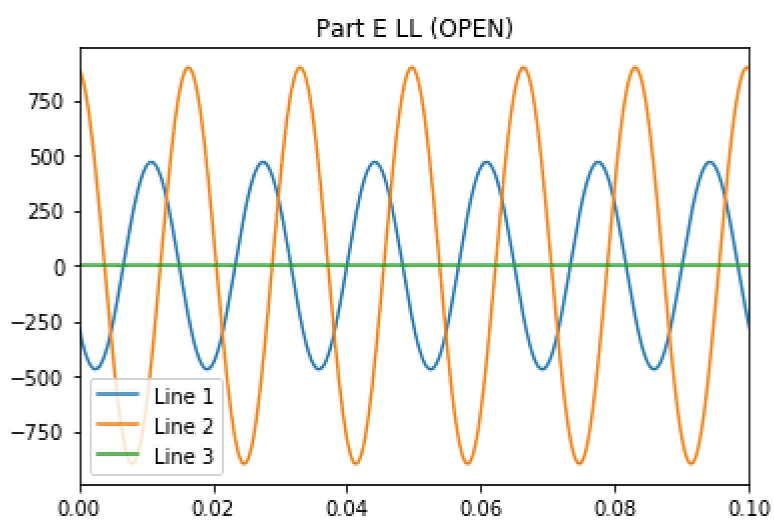
```
# Plot For Part E
atpdataplot("1_E_1_3PHS",title="Part E 3PHS (OPEN)",labels=["Line 1","Line 2
atpdataplot("1_E_2_3PHS",title="Part E 3PHS (CLOSED)",labels=["Line 1","Line
atpdataplot("1_E_1_SLG",title="Part E SLG (OPEN)",labels=["Line 1","Line 2",
atpdataplot("1_E_2_SLG",title="Part E SLG (CLOSED)",labels=["Line 1","Line 2

atpdataplot("1_E_1_LL",title="Part E LL (OPEN)",labels=["Line 1","Line 2","L
atpdataplot("1_E_2_LL",title="Part E LL (CLOSED)",labels=["Line 1","Line 2",
atpdataplot("1_E_1_DLG",title="Part E DLG (OPEN)",labels=["Line 1","Line 2",
atpdataplot("1_E_2_DLG",title="Part E DLG (CLOSED)",labels=["Line 1","Line 2
```

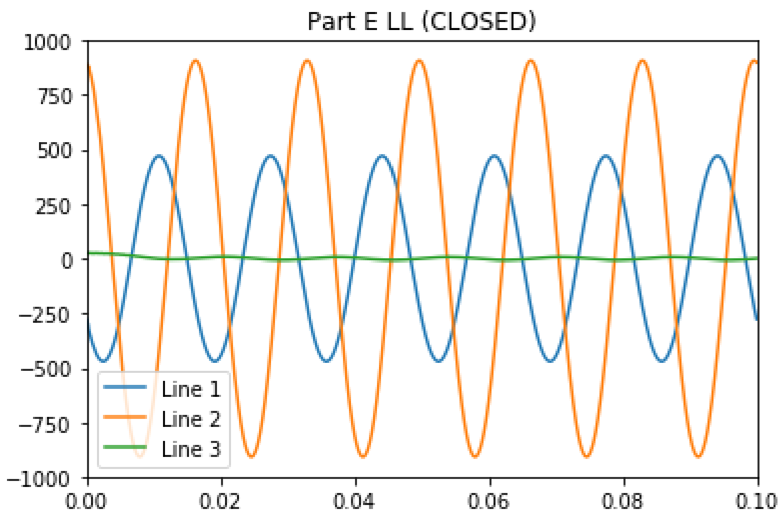


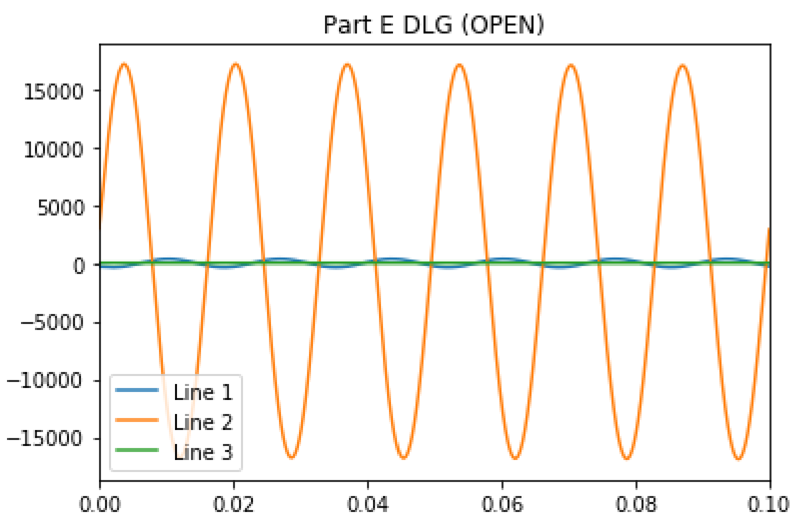


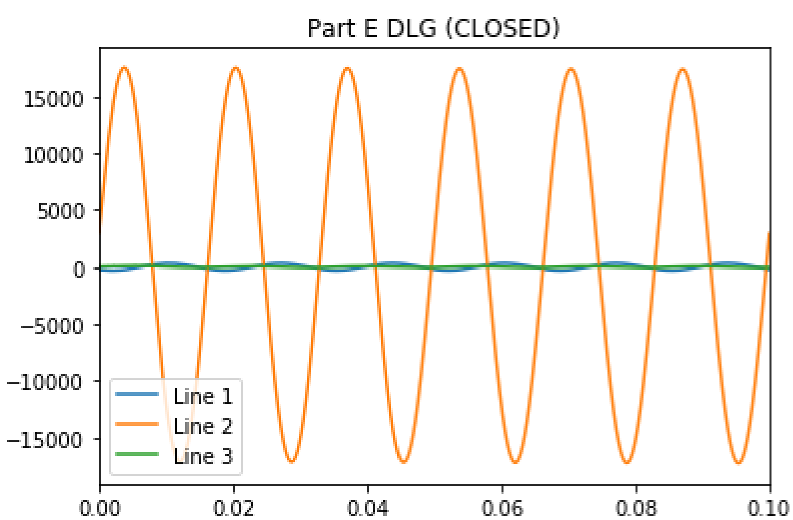

Part E SLG (OPEN)
15000
10000
5000
0
−5000
−10000
−15000
0.00
0.02
0.04
0.06
0.08
0.10
Line 1
Line 2
Line 3


Part E SLG (CLOSED)
15000
10000
5000
0
−5000
−10000
−15000
0.00
0.02
0.04
0.06
0.08
0.10
Line 1
Line 2
Line 3


Part E LL (OPEN)
750
500
250
0
−250
−500
−750
0.00
0.02
0.04
0.06
0.08
0.10
Line 1
Line 2
Line 3







Part F Discussion:

In every case above, we note a coupling factor between the faulted system and the unfaulted systems. Interestingly enough, the SLG Fault seems to have the most effect on the adjacent line.

Problem 2:

A)

Assume that velocity characteristics are as described from Midterm Exam:

$$v_0 = 1.2254 * 10^5 * \frac{mi}{sec}$$

$$v_1 = 1.8213 * 10^5 * \frac{mi}{sec}$$

$$v_2 = 1.8213 * 10^5 * \frac{mi}{sec}$$

In [24]:
```
# Calculate Part A:
dt = 1*u # second
v0 = 1.2254e5 # mi/sec
v1_2 = 1.8212e5 # mi/sec
accuracy = dt*v1_2
print("Accuracy of Location:",accuracy,"mi")
```

```
Accuracy of Location: 0.18212 mi
```

The accuracy of fault location will be different from that of an overhead transmission line due to the inherent difference in propogation velocity, an effect of the difference in cable arangement and cable parameters (R/L/C). Other factors that will affect the accuracy include the variety of underground objects and variation of soil consistency and moisture, among other factors.

We should aim to avoid usage of the ground/zero mode due to the fact that it attenuates and distorts values; instead, we should use the first/(alpha) and second/(beta) line modes. The distortion related to the ground mode comes from factors like those described above. Underground objects and variation in the ground makeup will inevitably distort the methods used for traveling wave detection/location.

B)

To determine flashover characteristics in a lightning strike situation, only the pertinent grounding mechanism needs to be modeled thoroughly, the remaining pieces of the grounding system may be reduced to thevenin equivalent circuits. In the case of the 100 mile transmission line, only the nearby towers and grounding system need to be modeled thoroughly.

The lighting strike should be modeled as a current source. After all, lightning is really just the discharge of electrically charged clouds, and the change of charge over time is current.

C)

Larger footing resistances will actually help to reduce the risk of a back flashover, this is because with the increased resistance, there will be a lower potential difference (voltage) between the ground conductor and the phase conductors. This results in a lower chance of flashover. This resistance must be great compared to the impedance between the tower phase conductor and ground conductor.

D)

1. Rules of Thumb:
   - Easy to apply
   - Quick application
   - Does not account for system specific parameters
   - May over/under estimate the system
2. Deterministic Studies:
   - Requires in-depth system analyis, modeling, and calculation
   - Highly accurate as compared to (1)
   - May largely overstate the insulation requirements
   - Higher than necessary cost due to previous bullet
3. Statistical Studies:
   - Attempt to account for "most likely" requirements
   - Likely will lead to lower costs than (2)
   - Likely will lead to greater accuracy than (1)
   - May not account for all cases
   - May not accurately generate the "most likely" requirements as result of pseudo-randomness

E)

Ground wires affect the R', L', and C' values by providing an object for mutual coupling to occur with. There is always one ground mode, regardless of the number of static wires because of the fact that all ground returns share a common path, and thus common characteristics.

Having a segmented or continuous ground wire will only affect the coupling parameters for the phase conductors. It will not affect the ground mode as there is still one path for the ground return.

F)

Frequency dependent distributed models will be especially useful for switching studies, and for fault studies where multiple lengths of line must be tested and modeled.

Cables will be useful in modeling line interactions and coupling in addition to line charging and faulted line interaction.

G)

- BIL stands for "basic lightning impulse insulation level", and as described in class, it describes: "Rise time of 1.2μsec and decay to 50% in 50μsec"
- BSL stands for "basic switching impulse insulation level", and it describes: "Rise time of 250μsec and decay to 50% in 2500μsec"

Both of these standards are used to describe the ability of equipment and insulation to withstand overvoltages.

H)

Transformers modeled for high-frequency transient analysis must include capacitive characteristics that models designed for low frequency analysis often don't include. This is because of the increased importance of capacitance in high-frequency ranges.

These differences tend to appear in the neighborhood of 20kHz.

Saturation tends to be more important and more prevalent in lower frequency ranges, and as a result, that is why low-frequency transformers tend to be larger in physical size.

In [ ]:
```

```