

# Joe Stanley

## ECE522 - EXAM1

```
In [1]: 1 # Import Necessary Libraries
2 import numpy as np
3 _np = np
4 import matplotlib.pyplot as plt
5 from scipy.optimize import fsolve
6 import electricpy as ep
7 from electricpy import compose
8 from electricpy.constants import *
9
10 # Set Boolean Control for Report Style
11 debug = True
```

### Problem I:

#### Part A:

Given the parameters described below, find:  $\text{slip}_{\text{rated}}$ ,  $\omega_{r-\text{rated}}$ , and  $\Lambda_{dr_{\text{rated}}}$ . Rated is defined to mean that the operating conditions are such that:  $|V_{dqs}| = 1.0\text{pu}$ ,  $T_{em} = 1.0\text{pu}$ , and  $\omega_{es} = 1.0\text{pu}$

For this, we know:

$$V_{dqs} = r_s I_{dqs} + j\omega_{es} \left( L_s I_{dqs} + \frac{3}{2} L_{sr} I_{dqr} \right)$$

$$0 = r_r I_{dqr} + j(\omega_{es} - \omega_r) \Lambda_{dqr}$$

$$\Lambda_{dqr} = \frac{3}{2} L_{sr} I_{dqs} + L_r I_{dqr}$$

$$T_{em} = \frac{3p}{4} \frac{\frac{3}{2} L_{sr}}{L_r} \text{Im} \left( \overline{\Lambda_{dqr}} I_{dqs} \right)$$

Additionally, we will need to use a few additional equations to solve this system.

$$L_s = L_{LS} + L_m$$

$$L_r = L_{Lr} + L_m$$

$$L_{sr} = \frac{2}{3} \cdot (L_r - L_{Lr}) \cdot a_t$$

As a final note, we will make the following assumptions:

$$p = 4 \quad a_t = 2$$

Using an iterative solver (shown in code below), we can now find the terms as:

**NameError:** name 'P1\_latex' is not defined

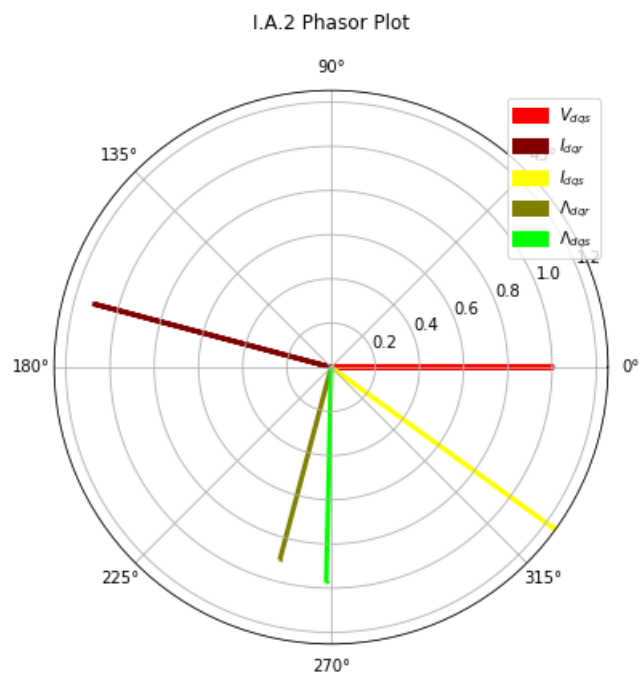
In [7]:

```
1  # Define Provided Machine Parameters
2  rs = 0.03 #pu
3  LLs = 0.1 #pu
4  Lm = 2.0 #pu
5  LLr = 0.1 #pu
6  rr = 0.03 #pu
7
8  # Define Rated Criteria
9  VdqsMag = 1
10 Tem = 1
11 wes = 1
12
13 # Calculate Additional Inductance Terms
14 Ls = LLs + Lm
15 Lr = LLr + Lm
16
17 #####
18 # A.1)
19
20 Vds = VdqsMag
21 Vqs = 0
22 Idqr, Idqs, LAMdqr, LAMdqs, s_rated, w_rated, lamdr_rated = ep.indmachfocratings(rr,rs,Lm,LLr=LLr,LLs=LLs)
23 clist = np.array([VdqsMag, Idqr, Idqs, LAMdqr, LAMdqs])
24
25 # Generate into Latex Vector
26 vect_desc = (r"$$\begin{bmatrix}V_{\text{dqs}}\\I_{\text{dqr}}\\r"I_{\text{dqs}}\\\\Lambda_{\text{dqr}}\\ \Lambda_{\text{dqs}}\end{bmatrix}"+
27              r"\end{bmatrix}=")
28
29 P1_latex = vect_desc + ep.clatex(clist,predollar=False,double=True)
30
31 print("S-rated:",s_rated,"\tw-rated:",w_rated,"\tLambda-rated:",lamdr_rated)
32 # Write Results to Data File
33 with open("constants.txt",'w') as file:
34     file.write(str(s_rated)+'\n')
35     file.write(str(w_rated)+'\n')
36     file.write(str(lamdr_rated)+'\n')
37
38 #####
39 # A.2)
40 # Use Complex Values to Plot Phasor Diagram
41 texlabels = [
42     "$V_{dqs}$",
43     "$I_{dqr}$",
44     "$I_{dqs}$",
45     "$\\Lambda_{dqr}$",
46     "$\\Lambda_{dqs}$",
47 ]
48 labels = [
49     "Vdqs:",
50     "Idqr:",
51     "Idqs:",
52     "\tdqr:",
53     "\tdqs:",
54 ]
55 ep.phasorplot(clist,"I.A.2 Phasor Plot",texlabels,filename="I-A-2",size=6,linewidth=3,plot=debug)
56 ep.cprint(clist,label=labels,pretty=True)
57
58 #####
59 # A.3)
60 # Calculate Phase Shift
61 shift = np.angle(LAMdqr,deg=True)
62 # Shift Phasors by Phase Shift Specified
63 clist *= ep.phs(-shift)
64 # Use Complex Values to Plot Phasor Diagram
65 ep.phasorplot(clist,"I.A.3 Phasor Plot",texlabels,filename="I-A-3",size=6,linewidth=3,plot=debug)
66 ep.cprint(clist,label=labels,pretty=True)
```

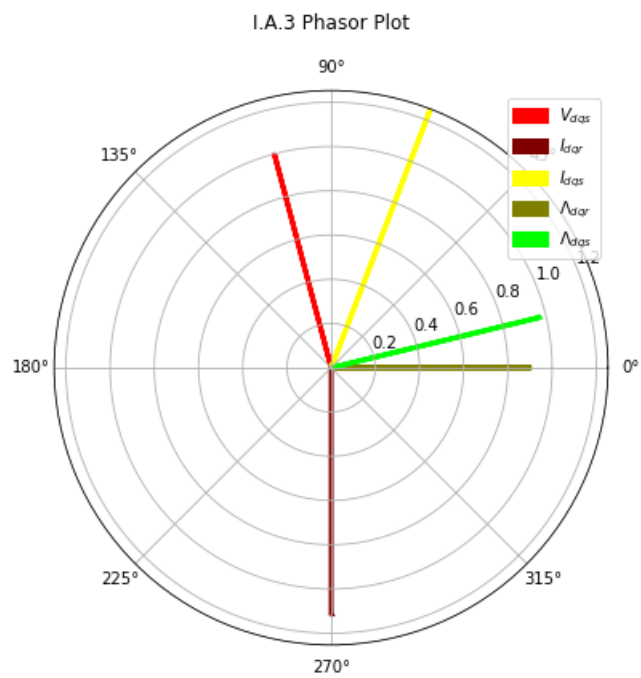
S-rated: 0.03723079497495241

$\omega$ -rated: 0.9627692050250476

Lambda-rated: 0.8976550377456242



$V_{dqs}$ : 1.0  $\angle$  0.0°  
 $I_{dqr}$ : 1.114  $\angle$  165.077°  
 $I_{dqs}$ : 1.253  $\angle$  -35.915°  
 $\lambda_{dqr}$ : 0.898  $\angle$  -104.923°  
 $\lambda_{dqs}$ : 0.97  $\angle$  -91.303°



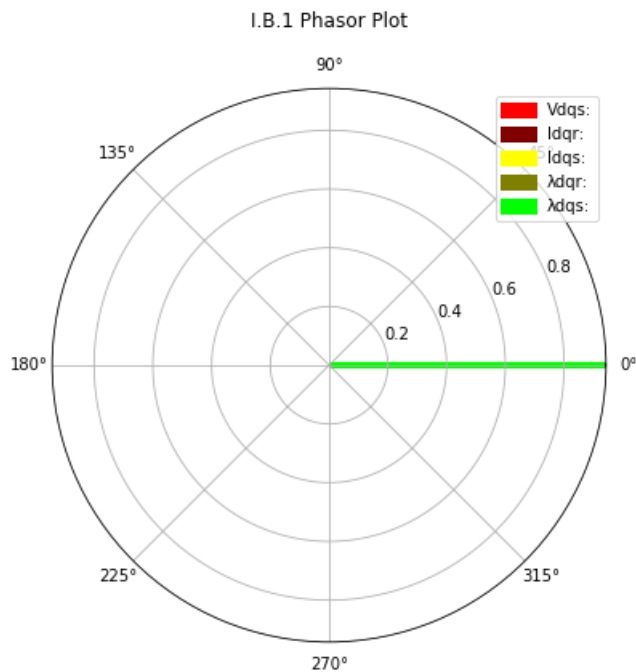
$V_{dqS}: 1.0 \angle 104.923^\circ$   
 $I_{dqr}: 1.114 \angle -90.0^\circ$   
 $I_{dqs}: 1.253 \angle 69.008^\circ$   
 $\lambda_{dqr}: 0.898 \angle -0.0^\circ$   
 $\lambda_{dqs}: 0.97 \angle 13.62^\circ$

**Part B:**

In [3]:

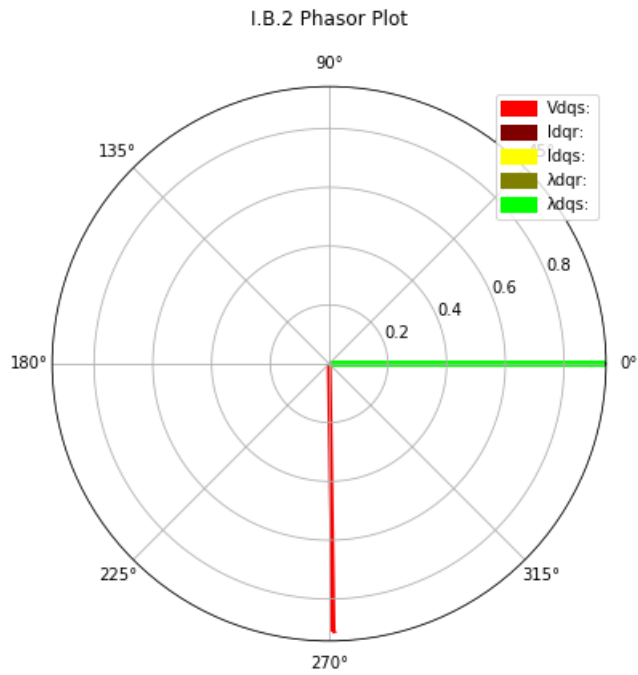
```
1  # Re-Define Known Values
2  Tem = 0
3
4  #####
5  # B.1)
6  wr = 0.0
7  LAMdr = lamdr Rated
8
9  # Generate Phasor Plot
10 Vdqs, Idqr, Idqs, LAMdqr, LAMdqs, wslip, wes = ep.imfoc_control(Tem, LAMdr, wr, rr, rs, Lm, LLr, LLs)
11 clist = [Vdqs, Idqr, Idqs, LAMdqr, LAMdqs]
12 print("w-slip:", wslip, "\tw-es", wes)
13 ep.phasorplot(clist, "I.B.1 Phasor Plot", labels, filename="I-B-1", size=6, linewidth=3, plot=debug)
14 ep.cprint(clist, label=labels, pretty=True)
15
16 #####
17 # B.2)
18 wr = w Rated
19 LAMdr = lamdr Rated
20
21 # Generate Phasor Plot
22 Vdqs, Idqr, Idqs, LAMdqr, LAMdqs, wslip, wes = ep.imfoc_control(Tem, LAMdr, wr, rr, rs, Lm, LLr, LLs)
23 clist = [Vdqs, Idqr, Idqs, LAMdqr, LAMdqs]
24 print("w-slip:", wslip, "\tw-es", wes)
25 ep.phasorplot(clist, "I.B.2 Phasor Plot", labels, filename="I-B-2", size=6, linewidth=3, plot=debug)
26 ep.cprint(clist, label=labels, pretty=True)
27
28 #####
29 # B.3)
30 wr = 2*w Rated
31 LAMdr = lamdr Rated/2
32
33 # Generate Phasor Plot
34 Vdqs, Idqr, Idqs, LAMdqr, LAMdqs, wslip, wes = ep.imfoc_control(Tem, LAMdr, wr, rr, rs, Lm, LLr, LLs)
35 clist = [Vdqs, Idqr, Idqs, LAMdqr, LAMdqs]
36 print("w-slip:", wslip, "\tw-es", wes)
37 ep.phasorplot(clist, "I.B.3 Phasor Plot", labels, filename="I-B-3", size=6, linewidth=3, plot=debug)
38 ep.cprint(clist, label=labels, pretty=True)
```

w-slip: 0.0      w-es 0.0



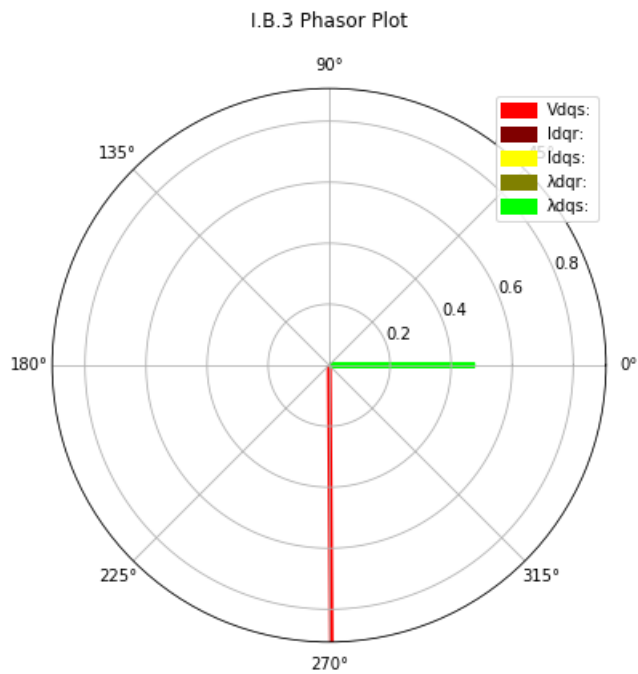
Vdqs: 0.013 ∠ 0.0°  
Idqr: 0.0 ∠ 0.0°  
Idqs: 0.449 ∠ 0.0°  
λdqr: 0.898 ∠ 0.0°  
λdqs: 0.943 ∠ 0.0°

w-slip: 0.0      w-es 0.9627692050250476



$V_{dq}$ : 0.908  $\angle$  -89.15°  
 $I_{dq}$ : 0.0  $\angle$  0.0°  
 $I_{dq}^*$ : 0.449  $\angle$  0.0°  
 $\lambda_{dq}$ : 0.898  $\angle$  0.0°  
 $\lambda_{dq}^*$ : 0.943  $\angle$  0.0°

w-slip: 0.0      w-es 1.9255384100500952



$V_{dq}$ : 0.907  $\angle$  -89.575°  
 $I_{dq}$ : 0.0  $\angle$  0.0°  
 $I_{dq}^*$ : 0.224  $\angle$  0.0°  
 $\lambda_{dq}$ : 0.449  $\angle$  0.0°  
 $\lambda_{dq}^*$ : 0.471  $\angle$  0.0°

**Part C:**



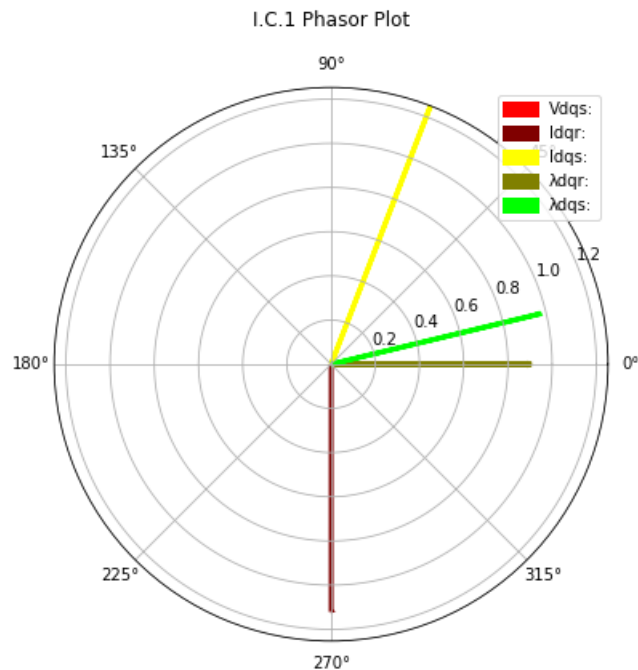
In [4]:

```

1  # C.1)
2  Tem = 1.0
3  wr = 0.0
4  LAMdr = lamdr_rated
5
6  # Generate Phasor Plot
7  Vdqs, Idqr, Idqs, LAMdqr, LAMdqs, wslip, wes = ep.imfoc_control(Tem, LAMdr, wr, rr, rs, Lm, LLr, LLs)
8  clist = [Vdqs, Idqr, Idqs, LAMdqr, LAMdqs]
9  print("w-slip:", wslip, "\tw-es", wes)
10 ep.phasorplot(clist, "I.C.1 Phasor Plot", labels, filename="I-C-1", size=6, linewidth=3, plot=debug)
11 ep.cprint(clist, label=labels, pretty=True)
12
13 #####
14 # C.2)
15 Tem = 1.0
16 wr = w_rated
17 LAMdr = lamdr_rated
18
19 # Generate Phasor Plot
20 Vdqs, Idqr, Idqs, LAMdqr, LAMdqs, wslip, wes = ep.imfoc_control(Tem, LAMdr, wr, rr, rs, Lm, LLr, LLs)
21 clist = [Vdqs, Idqr, Idqs, LAMdqr, LAMdqs]
22 print("w-slip:", wslip, "\tw-es", wes)
23 ep.phasorplot(clist, "I.C.2 Phasor Plot", labels, filename="I-C-2", size=6, linewidth=3, plot=debug)
24 ep.cprint(clist, label=labels, pretty=True)
25
26 #####
27 # C.3)
28 Tem = 0.5
29 wr = 2*w_rated
30 LAMdr = lamdr_rated/2
31
32 # Generate Phasor Plot
33 Vdqs, Idqr, Idqs, LAMdqr, LAMdqs, wslip, wes = ep.imfoc_control(Tem, LAMdr, wr, rr, rs, Lm, LLr, LLs)
34 clist = [Vdqs, Idqr, Idqs, LAMdqr, LAMdqs]
35 print("w-slip:", wslip, "\tw-es", wes)
36 ep.phasorplot(clist, "I.C.3 Phasor Plot", labels, filename="I-C-3", size=6, linewidth=3, plot=debug)
37 ep.cprint(clist, label=labels, pretty=True)

```

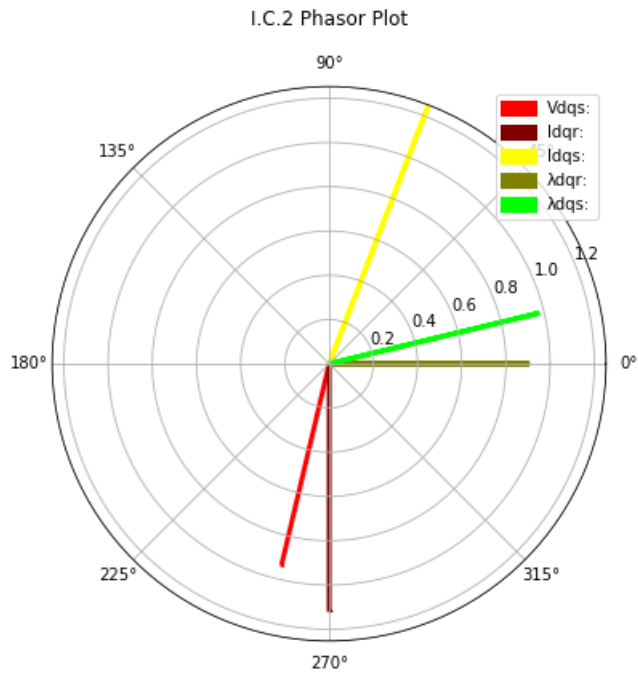
w-slip: 0.03723079497477497      w-es 0.03723079497477497



Vdqs: 0.005  $\angle$  0.0°  
 Idqr: 1.114  $\angle$  -90.0°  
 Idqs: 1.253  $\angle$  69.008°  
 λdqr: 0.898  $\angle$  0.0°  
 λdqs: 0.97  $\angle$  13.62°

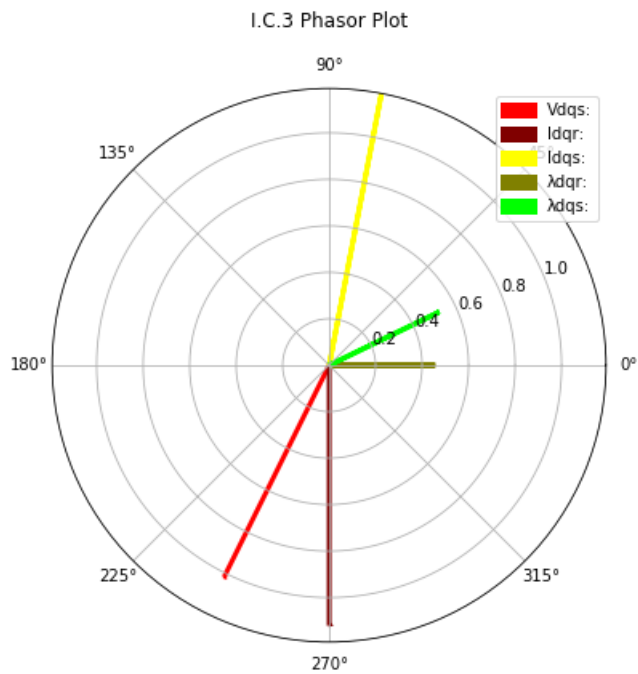


w-slip: 0.03723079497477497 w-es 0.9999999999998226



Vdqs: 0.933  $\angle$  -103.324°  
Idqr: 1.114  $\angle$  -90.0°  
Idqs: 1.253  $\angle$  69.008°  
λdqr: 0.898  $\angle$  0.0°  
λdqs: 0.97  $\angle$  13.62°

w-slip: 0.07446158994954993 w-es 1.9999999999996452



Vdqs: 1.013  $\angle$  -116.377°  
Idqr: 1.114  $\angle$  -90.0°  
Idqs: 1.191  $\angle$  79.14°  
λdqr: 0.449  $\angle$  0.0°  
λdqs: 0.524  $\angle$  25.854°

In [ ]:

1

In [ ]:

1	
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