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ECE522 - EXAM1

In [1]:
```
# Import Necessary Libraries
import numpy as np
_np = np
import matplotlib.pyplot as plt
from scipy.optimize import fsolve
import electricpy as ep
from electricpy import compose
from electricpy.constants import *

# Set Boolean Control for Report Style
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:

$$V_{dqs} = r_s I_{dqs} + j\omega_{es}\left(L_s I_{dqs} + \tfrac{3}{2} L_{sr} I_{dqr}\right)$$
$$0 = r_r I_{dqr} + j(\omega_{es} - \omega_r)\Lambda_{dqr}$$
$$\Lambda_{dqr} = \tfrac{3}{2} L_{sr} I_{dqs} + L_r I_{dqr}$$
$$T_{em} = \frac{3p}{4}\frac{\frac{3}{2}L_{sr}}{L_r}\text{Im}\left(\overline{\Lambda_{dqr}} I_{dqs}\right)$$

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

$$L_s = L_{LS} + L_m$$
$$L_r = L_{Lr} + L_m$$
$$L_{sr} = \tfrac{2}{3} \cdot (L_r - L_{Lr}) \cdot a_t$$

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

$$p = 4 \qquad a_t = 2$$

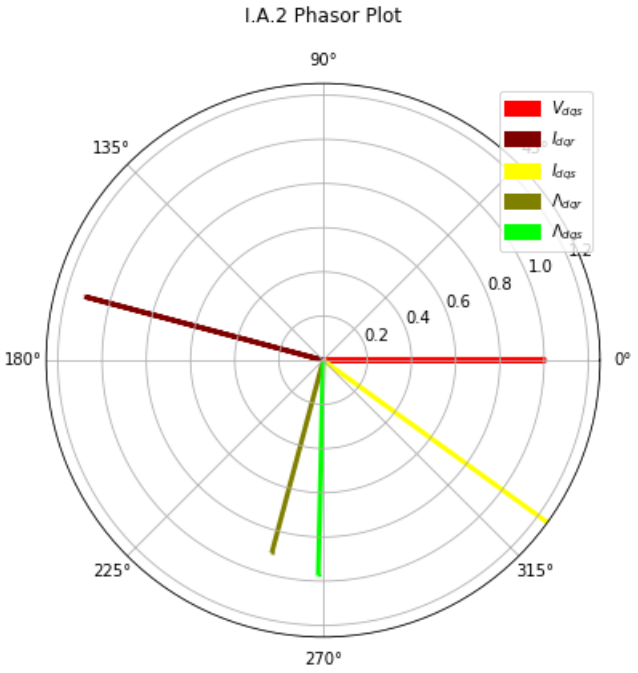
Using an iterative solver (shown in code below), we can now find the terms as:

NameError: name 'P1_latex' is not defined

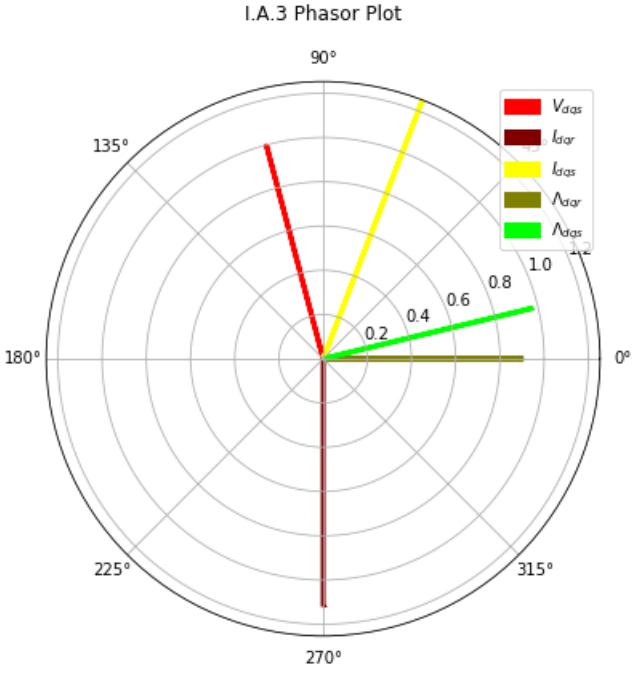
In [7]:

```python
# Define Provided Machine Parameters
rs = 0.03 #pu
LLs = 0.1 #pu
Lm = 2.0 #pu
LLr = 0.1 #pu
rr = 0.03 #pu

# Define Rated Criteria
VdqsMag = 1
Tem = 1
wes = 1

# Calculate Additional Inductance Terms
Ls = LLs + Lm
Lr = LLr + Lm

########################################################################
# A.1)

Vds = VdqsMag
Vqs = 0
Idqr,Idqs,LAMdqr,LAMdqs,s_rated,w_rated,lamdr_rated = ep.indmachfocratings(rr,rs,Lm,Llr=LLr,Lls=LLs)
clist = np.array([VdqsMag,Idqr,Idqs,LAMdqr,LAMdqs])

# Generate into Latex Vector
vect_desc = (r"$$\begin{bmatrix}V_{\text{dqs}}\\I_{\text{dqr}}\\"+
             r"I_{\text{dqs}}\\\Lambda_{\text{dqr}}\\ \Lambda_{\text{dqr}}"+
             "\end{bmatrix}=")
P1_latex = vect_desc + ep.clatex(clist,predollar=False,double=True)

print("S-rated:",s_rated,"\tω-rated:",w_rated,"\tLambda-rated:",lamdr_rated)
# Write Results to Data File
with open("constants.txt",'w') as file:
    file.write(str(s_rated)+'\n')
    file.write(str(w_rated)+'\n')
    file.write(str(lamdr_rated)+'\n')

########################################################################
# A.2)
# Use Complex Values to Plot Phasor Diagram
texlabels = [
    "$V_{dqs}$",
    "$I_{dqr}$",
    "$I_{dqs}$",
    "$\\Lambda_{dqr}$",
    "$\\Lambda_{dqs}$",
]
labels = [
    "Vdqs:",
    "Idqr:",
    "Idqs:",
    "λdqr:",
    "λdqs:",
]
ep.phasorplot(clist,"I.A.2 Phasor Plot",texlabels,filename="I-A-2",size=6,linewidth=3,plot=debug)
ep.cprint(clist,label=labels,pretty=True)

########################################################################
# A.3)
# Calculate Phase Shift
shift = np.angle(LAMdqr,deg=True)
# Shift Phasors by Phase Shift Specified
clist *= ep.phs(-shift)
# Use Complex Values to Plot Phasor Diagram
ep.phasorplot(clist,"I.A.3 Phasor Plot",texlabels,filename="I-A-3",size=6,linewidth=3,plot=debug)
ep.cprint(clist,label=labels,pretty=True)
```

```
S-rated: 0.03723079497495241    ω-rated: 0.9627692050250476    Lambda-rated: 0.8976550377456242
```



Vdqs: 1.0 ∠ 0.0°
Idqr: 1.114 ∠ 165.077°
Idqs: 1.253 ∠ -35.915°
λdqr: 0.898 ∠ -104.923°
λdqs: 0.97 ∠ -91.303°



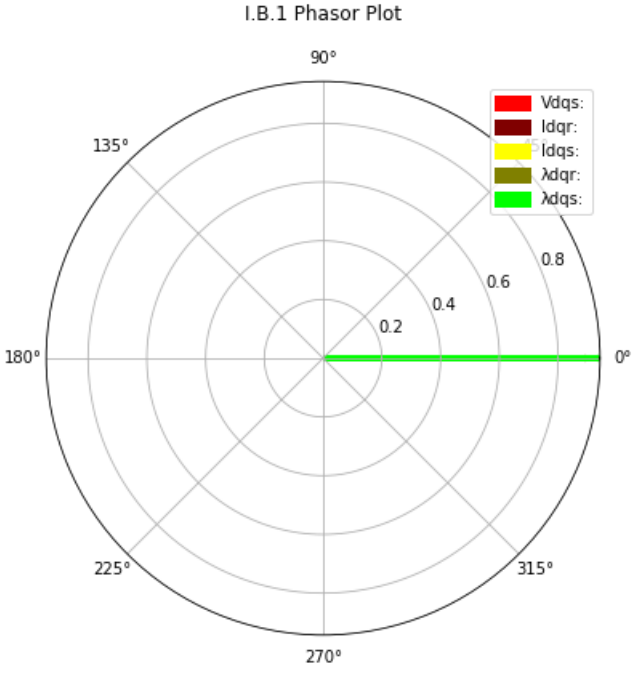
Vdqs: 1.0 ∠ 104.923°
Idqr: 1.114 ∠ -90.0°
Idqs: 1.253 ∠ 69.008°
λdqr: 0.898 ∠ -0.0°
λdqs: 0.97 ∠ 13.62°

Part B:

In [3]:

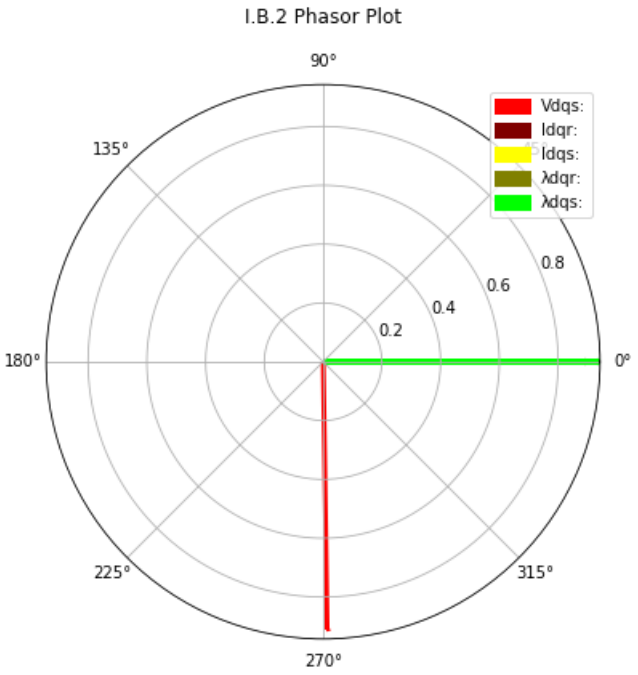
```
# Re-Define Known Values
Tem = 0

########################################################################
# B.1)
wr = 0.0
LAMdr = lamdr_rated

# Generate Phasor Plot
Vdqs,Idqr,Idqs,LAMdqr,LAMdqs,wslip,wes = ep.imfoc_control(Tem,LAMdr,wr,rr,rs,Lm,LLr,LLs)
clist = [Vdqs,Idqr,Idqs,LAMdqr,LAMdqs]
print("w-slip:",wslip,"\tw-es",wes)
ep.phasorplot(clist,"I.B.1 Phasor Plot",labels,filename="I-B-1",size=6,linewidth=3,plot=debug)
ep.cprint(clist,label=labels,pretty=True)

########################################################################
# B.2)
wr = w_rated
LAMdr = lamdr_rated

# Generate Phasor Plot
Vdqs,Idqr,Idqs,LAMdqr,LAMdqs,wslip,wes = ep.imfoc_control(Tem,LAMdr,wr,rr,rs,Lm,LLr,LLs)
clist = [Vdqs,Idqr,Idqs,LAMdqr,LAMdqs]
print("w-slip:",wslip,"\tw-es",wes)
ep.phasorplot(clist,"I.B.2 Phasor Plot",labels,filename="I-B-2",size=6,linewidth=3,plot=debug)
ep.cprint(clist,label=labels,pretty=True)

########################################################################
# B.3)
wr = 2*w_rated
LAMdr = lamdr_rated/2

# Generate Phasor Plot
Vdqs,Idqr,Idqs,LAMdqr,LAMdqs,wslip,wes = ep.imfoc_control(Tem,LAMdr,wr,rr,rs,Lm,LLr,LLs)
clist = [Vdqs,Idqr,Idqs,LAMdqr,LAMdqs]
print("w-slip:",wslip,"\tw-es",wes)
ep.phasorplot(clist,"I.B.3 Phasor Plot",labels,filename="I-B-3",size=6,linewidth=3,plot=debug)
ep.cprint(clist,label=labels,pretty=True)
```

```
w-slip: 0.0     w-es 0.0
```



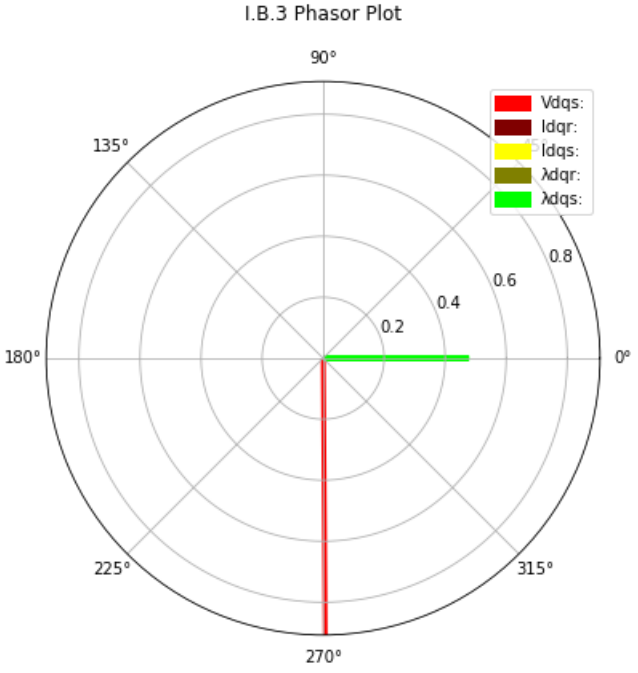

```
Vdqs: 0.013 ∠ 0.0°
Idqr: 0.0 ∠ 0.0°
Idqs: 0.449 ∠ 0.0°
λdqr: 0.898 ∠ 0.0°
λdqs: 0.943 ∠ 0.0°
```

w-slip: 0.0   w-es 0.9627692050250476



Vdqs: 0.908 ∠ -89.15°
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 1.9255384100500952



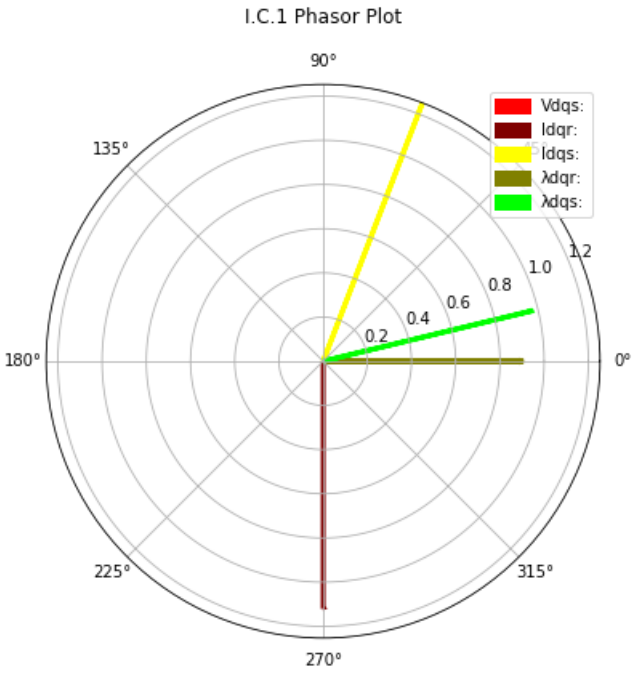
Vdqs: 0.907 ∠ -89.575°
Idqr: 0.0 ∠ 0.0°
Idqs: 0.224 ∠ 0.0°
λdqr: 0.449 ∠ 0.0°
λdqs: 0.471 ∠ 0.0°

Part C:

In [4]:

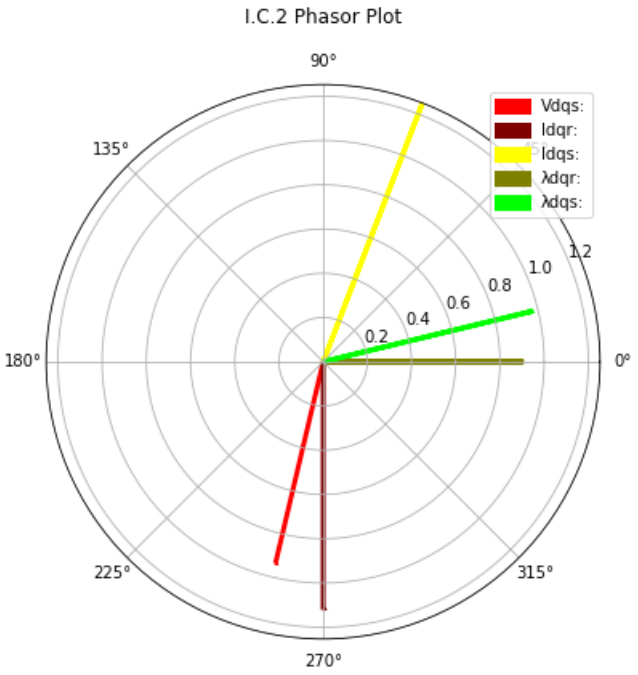
```
# C.1)
Tem = 1.0
wr = 0.0
LAMdr = lamdr_rated

# Generate Phasor Plot
Vdqs,Idqr,Idqs,LAMdqr,LAMdqs,wslip,wes = ep.imfoc_control(Tem,LAMdr,wr,rr,rs,Lm,LLr,LLs)
clist = [Vdqs,Idqr,Idqs,LAMdqr,LAMdqs]
print("w-slip:",wslip,"\tw-es",wes)
ep.phasorplot(clist,"I.C.1 Phasor Plot",labels,filename="I-C-1",size=6,linewidth=3,plot=debug)
ep.cprint(clist,label=labels,pretty=True)

########################################################################
# C.2)
Tem = 1.0
wr = w_rated
LAMdr = lamdr_rated

# Generate Phasor Plot
Vdqs,Idqr,Idqs,LAMdqr,LAMdqs,wslip,wes = ep.imfoc_control(Tem,LAMdr,wr,rr,rs,Lm,LLr,LLs)
clist = [Vdqs,Idqr,Idqs,LAMdqr,LAMdqs]
print("w-slip:",wslip,"\tw-es",wes)
ep.phasorplot(clist,"I.C.2 Phasor Plot",labels,filename="I-C-2",size=6,linewidth=3,plot=debug)
ep.cprint(clist,label=labels,pretty=True)

########################################################################
# C.3)
Tem = 0.5
wr = 2*w_rated
LAMdr = lamdr_rated/2

# Generate Phasor Plot
Vdqs,Idqr,Idqs,LAMdqr,LAMdqs,wslip,wes = ep.imfoc_control(Tem,LAMdr,wr,rr,rs,Lm,LLr,LLs)
clist = [Vdqs,Idqr,Idqs,LAMdqr,LAMdqs]
print("w-slip:",wslip,"\tw-es",wes)
ep.phasorplot(clist,"I.C.3 Phasor Plot",labels,filename="I-C-3",size=6,linewidth=3,plot=debug)
ep.cprint(clist,label=labels,pretty=True)
```

```
w-slip: 0.03723079497477497     w-es 0.03723079497477497
```



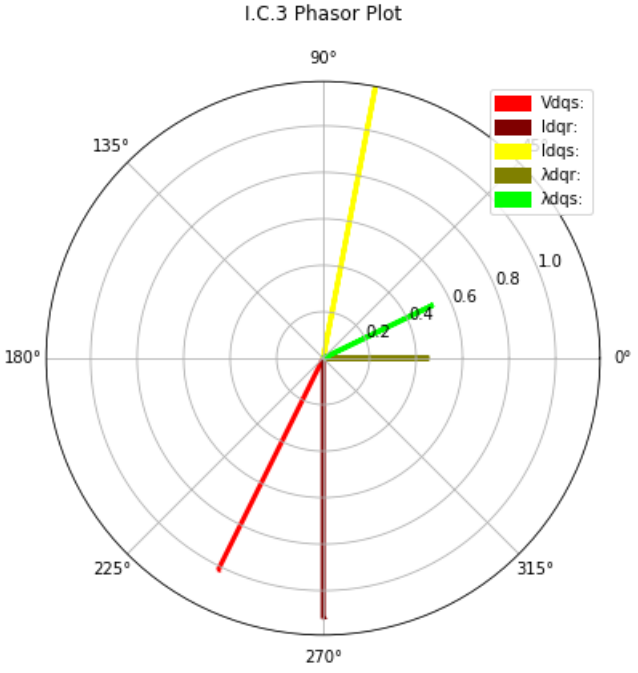

```
Vdqs: 0.005 ∠ 0.0°
Idqr: 1.114 ∠ -90.0°
Idqs: 1.253 ∠ 69.008°
λdqr: 0.898 ∠ 0.0°
λdqs: 0.97 ∠ 13.62°
```

```
w-slip: 0.03723079497477497     w-es 0.9999999999998226
```




```
Vdqs: 0.933 ∠ -103.324°
Idqr: 1.114 ∠ -90.0°
Idqs: 1.253 ∠ 69.008°
λdqr: 0.898 ∠ 0.0°
λdqs: 0.97 ∠ 13.62°
```

```
w-slip: 0.07446158994954993     w-es 1.9999999999996452
```




```
Vdqs: 1.013 ∠ -116.377°
Idqr: 1.114 ∠ -90.0°
Idqs: 1.191 ∠ 79.14°
λdqr: 0.449 ∠ 0.0°
λdqs: 0.524 ∠ 25.854°
```

In [ ]:
```
1
```

In [ ]:

```
1
```