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2016

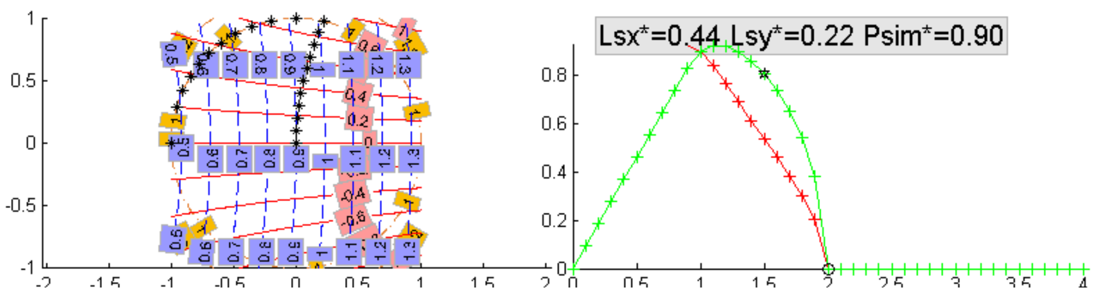
EIEN20 Assignment 5

5.2: Normalized characteristics of PMSM

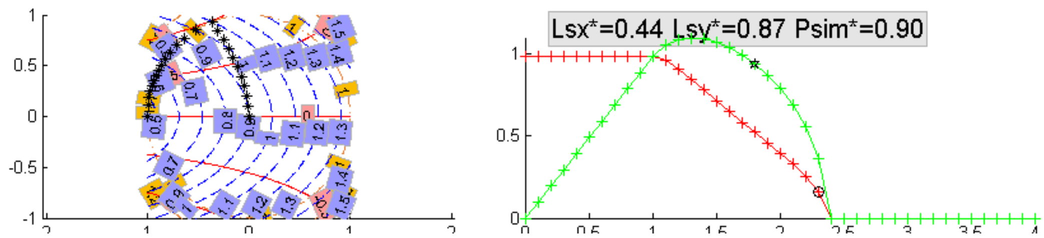
The first part of this assignment involved analysing the circle diagram and torque speed characteristic of a simulated induction motor.

I have some expectations of the results from this experiment from general magnetic behaviour. I expect a lower saliency to give a decreased power output, a lower torque and voltage output. Decreasing the PM Excitation Flux should increase output power and torque.

After running the script one time with the defined Saliency and PM Excitation Flux unchanged some effects are immediately clear from the output diagrams.
A saliency value of 1 produces the most stable torque degradation, a saliency of 0.5 gives a sharper fall in torque and 2 gives a more gentle decrease. Torque is decreased for the higher saliency; this is opposite to my previous expectation as I'd imagined the less aligned rotor to be driving more gently. The higher saliency also adds weight to the power curve, retaining power just slightly more than the others at higher rotational speeds.
The voltage lines in the circle diagrams become strait at saliency 0.5, I am currently unsure of the reason for this. The voltage values decrease slightly for lower saliencies also which does align with my expectations.



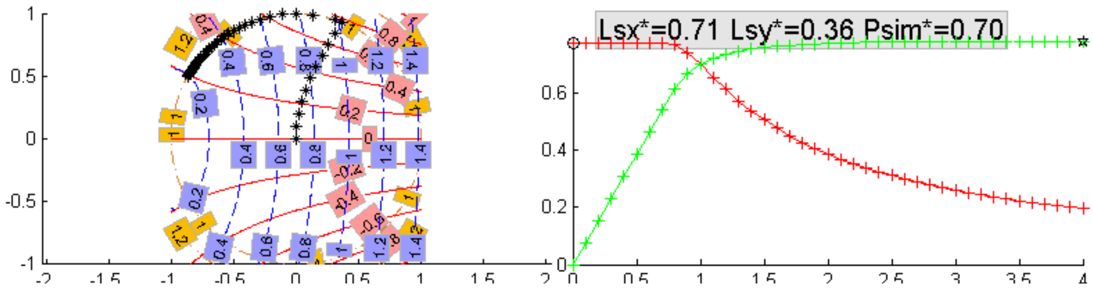
psim=0.9, ksii=0.5



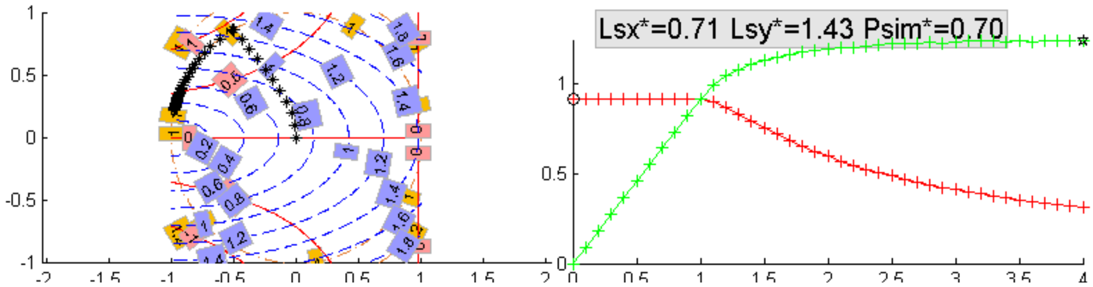
psim=0.9, ksii=2

The first alteration I tested was lowering the psim from 0.9 to 0.7, while retaining the saliency values.
This produced starkly different results from the first simulation; output power rises as torque decreases to a steady value. The saliency with the best power curve is the low value (0.5). This result meets my expectation but the rate of change is far larger than I

expected. This shows that reducing permanent magnet excitation flux a small amount can have a huge affect on the whole motor.
Torque is considerably lower for the reduced excitation flux, and lowest for the even saliency (1).

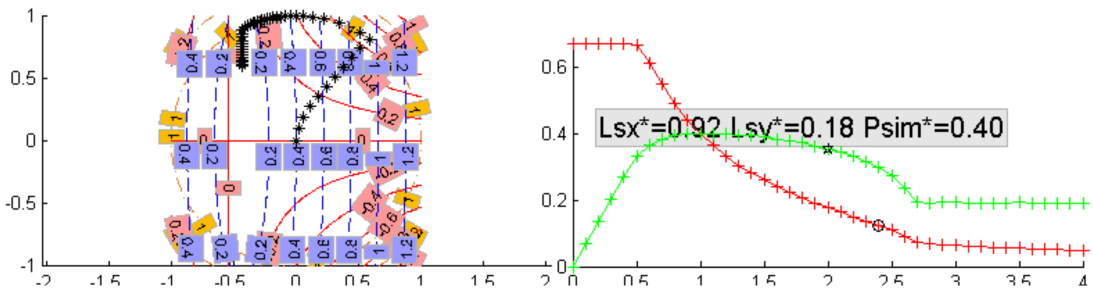


psim=0.7, ksii=0.5

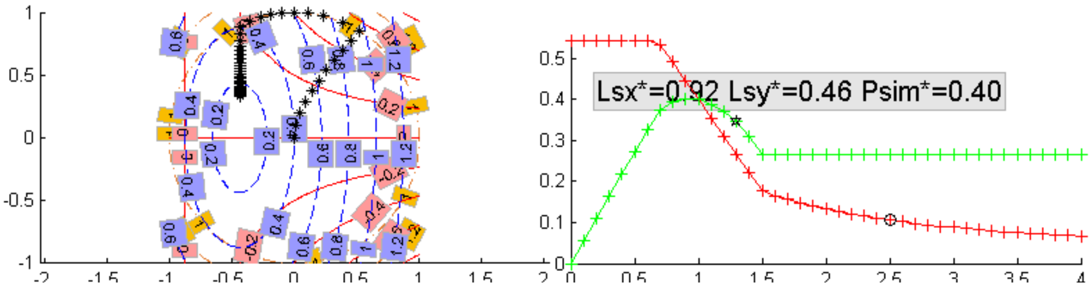


psim=0.7, ksii=2

After these observations I decided to reduce psim further and test some smaller ksii values around 0.5. My hope is to create a very stable, low power output.
As expected the results were very different from the first two simulations. The torque decreases gradually as above, the power output however is totally different. I think this is due to the extreme nature of these parameters, the output increases sharply due to such a low excitation frequency but decreases to a constant possibly from the low alignment inductance.
Another interesting observation is the difference in voltage ellipses as ksii changed from 0.5 to 0.8, I suspect there is some ksii value between these two that dictates the voltage behaviour.

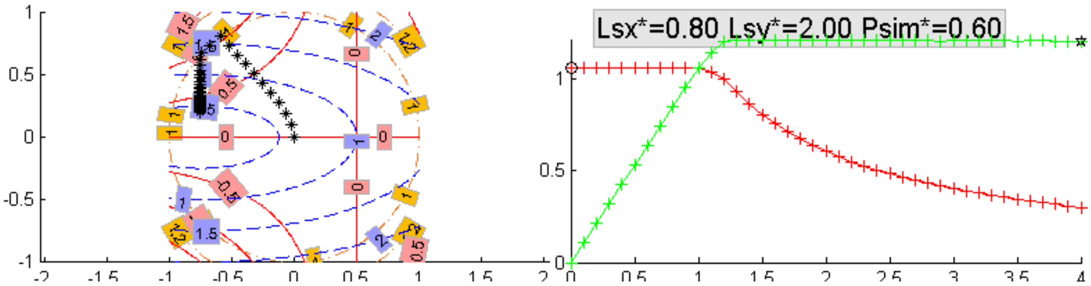


psim=0.4, ksii=0.2

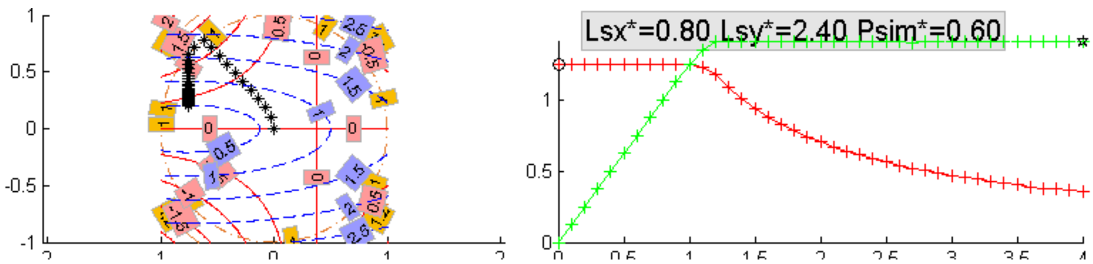


psim=0.4, ksii=0.5

For the last simulation I will increase saliency to 0.6 and also raise the ksii range in order to return to a stable power output.
These parameters produced similar results to what I was aiming for, a slow torque degredation and a steady output power of reasonable amplitude. The voltage and torque are nicely variable, torque becomes very steady for a saliency of 1 at this excitation flux.



psim=0.6, ksii=2.5



psim=0.6, ksii=3

5.3: Machine parameters from FE-model

The first job for this secondary assignment part was to change the parameters of the machine to match those that I used in assignment 4. As a reminder, the values I used are below:

Motor frame size	*Outer/Inner diameter Do/Di [mm]*	*Stack length lr [mm]*	*No. of poles N_p*	*Slotting factor K_s*	*Stator core inner radius [m]*
115	105/25	50	6	0.3	ro-(ro-ri)*0.7

After this, I ran the simulation and recorded the output.

Results:
Isy=In, Isx=0
rot position 0.0 deg e, current Im=626.9 A, angle=90.0 deg
phase currents: ia=0.00e+000 A , ib=5.43e+002 A , ic=-5.43e+002 A

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phase fluxes: fa=2.16e-003 Vs, fb=2.10e-004 Vs, fc=-2.38e-003 Vs
weighted torque calculated around rotor area: 6.81e+000 Nm
--
rot position 30.0 deg e, current Im=626.9 A, angle=90.0 deg
phase currents: ia=-3.13e+002 A , ib=6.27e+002 A , ic=-3.13e+002 A
phase fluxes: fa=1.25e-003 Vs, fb=1.45e-003 Vs, fc=-2.74e-003 Vs
weighted torque calculated around rotor area: 5.59e+000 Nm
--
Isy=0, Isx=0
rot position 0.0 deg e, current Im=0.0 A, angle=0.0 deg
phase currents: ia=0.00e+000 A , ib=0.00e+000 A , ic=0.00e+000 A
phase fluxes: fa=2.17e-003 Vs, fb=-1.08e-003 Vs, fc=-1.09e-003 Vs
weighted torque calculated around rotor area: 8.45e-003 Nm
--
rot position 30.0 deg e, current Im=0.0 A, angle=0.0 deg
phase currents: ia=0.00e+000 A , ib=0.00e+000 A , ic=0.00e+000 A
phase fluxes: fa=2.05e-003 Vs, fb=1.24e-006 Vs, fc=-2.05e-003 Vs
weighted torque calculated around rotor area: 4.05e-003 Nm
--
Isy=0, Isx=-Isn
rot position 0.0 deg e, current Im=626.9 A, angle=180.0 deg
phase currents: ia=-6.27e+002 A , ib=3.13e+002 A , ic=3.13e+002 A
phase fluxes: fa=6.66e-004 Vs, fb=-3.20e-004 Vs, fc=-3.23e-004 Vs
weighted torque calculated around rotor area: 3.69e-003 Nm
--
rot position 30.0 deg e, current Im=626.9 A, angle=180.0 deg
phase currents: ia=-5.43e+002 A , ib=0.00e+000 A , ic=5.43e+002 A
phase fluxes: fa=7.33e-004 Vs, fb=1.26e-006 Vs, fc=-7.34e-004 Vs
weighted torque calculated around rotor area: 2.10e-002 Nm
--
Is =1.0e+002 *

 0.0000 + 9.4036i
 -4.7018 + 8.1438i
 0
 0
 -9.4036 - 0.0000i
 -8.1438 - 4.7018i

Fs =
 0.0032 + 0.0022i
 0.0019 + 0.0036i
 0.0033 + 0.0000i
 0.0031 + 0.0018i
 0.0010 + 0.0000i
 0.0011 + 0.0006i
--
visualisation of vector components at 0 and 30 rotor position
no load flux
 fsx [Vs]

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0.0027
0.0029

change in fluxes and currents at load

isx [A]	fsx [Vs]	fsy [Vs]
-767.8036	-0.0018	-0.0000
-767.8036	-0.0019	-0.0000

isy [A]	fsx [Vs]	fsy [Vs]
767.8036	-0.0000	0.0018
767.8036	-0.0001	0.0018

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Flux averages:

0 Degrees: f=0.000013/9 = 0.0000014 Vs
|f|=0.00116 Vs

30 Degrees: f=-0.0000385/9 = -0.000004278 Vs
|f|=0.001223 Vs

1.)

2.)

$$L_{sx} = \frac{\Delta\psi_{sx}}{\Delta I_{sx}} = \frac{((0.0011+0.0006i) - (0.0010+0i))}{((-8.1438-4.7018i) - (-9.4036-0i))\cdot 10^{3}}$$

$$L_{sx} = \frac{0.0001+0.0006i}{1259.8-4701.8i} = (-1.136+1.516i)\mu H$$

3.)

$$L_{sy} = \frac{\Delta\psi_{sy}}{\Delta I_{sy}} = \frac{((0.0019+0.0036i) - (0.0032+0.0022i))}{((-4.7018+8.1438i) - (0+9.4036i))\cdot 10^{3}}$$

$$L_{sy} = \frac{-0.0013+0.0014i}{-4701.8-1259.8i} = (1.8353-3.4693i)\mu H$$

After creating the modified FE-model as instructed, I ran the Matlab code for the new model, recorded the results and calculated machine parameters as before.

$$L_{sx} = \frac{\Delta\psi_{sx}}{\Delta I_{sx}} = \frac{((0.0009+0.0005i) - (0.0003+0i))}{((-8.1438-4.7018i) - (-9.4036-0i))\cdot 10^{3}}$$

$$L_{sx} = \frac{0.0006+0.0005i}{1259.8-4701.8i} = (-0.6728+1.4545i)\mu H$$

$$L_{sy} = \frac{\Delta\psi_{sy}}{\Delta I_{sy}} = \frac{((0.0007+0.0048i) - (0.0028+0.0036i))}{((-4.7018+8.1438i) - (0+9.4036i))\cdot 10^{3}}$$

$$L_{sy} = \frac{-0.0021+0.0012i}{-4701.8-1259.8i} = (3.5292-3.4978i)\mu H$$