ECE 331 - Solution to Homework #5

AC Induction Motors used as generators and single-phase operation

3-phase induction motors / generators:

1) Write a subrintine in MATLAB or SciLab which allows you to input the resistance and reactance (r1, r2, x1, x2), and returns the output torque, power, and efficiency for a slip from -1 to +1.

a) Modify the previous routine so you pass slip and r2:

```
function [To, Po, eff] = slip(s, r2)
```

b) Write another routine to call slip:

```
function [X] = TvsS(r2)

s = [0.01:0.01:0.99]';
To = 0*s;
Po = 0*s;
eff = 0*s;

for i=1:length(s)
   [To(i),Po(i),eff(i)] = slip(s(i),r2);
 end

 plot(1-s,To);

 X = To(length(s)) / max(To);


endfunction
```

Assume a three-phase, two pole, 20hp, $120V_{LN}$ (line-to-neutral), 60Hz, Y connected induction motor.

Assume the stator core losses are 500W and the rotational losses are 400W. At no-load, the motor draws 10A with a power factor of 0.1 lagging.

2) Plot the torque vs. speed relationship for this motor with

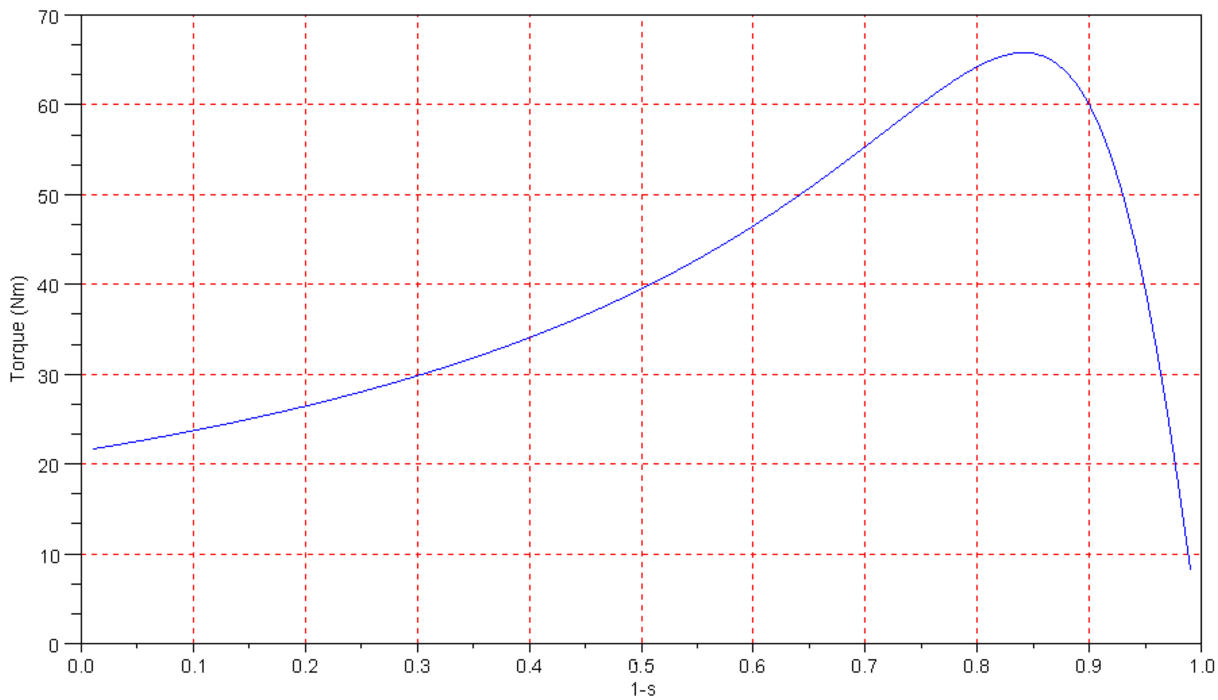
r1 = 0.1 Ohm, x1 = 0.35 Ohms

r2 = 0.12 Ohms   x2 = 0.40 Ohms

Now the routine from problem #1 with r2 = 0.12

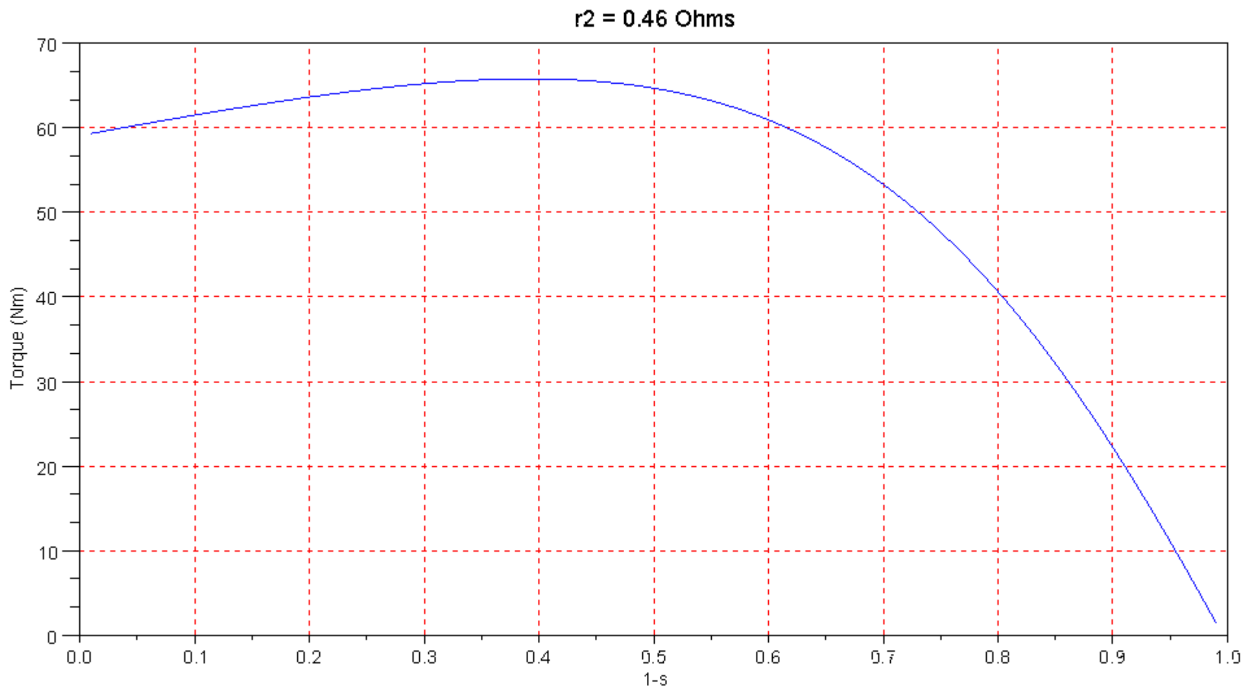
```
-->X = TvsS(0.12)
 X  =

    0.3290103
```

(The starting torque is 32.9% of the peak torque - used in problem #3)



3) Find r2 so that the starting torque is 90% of the peak torque.

```
-->X = TvsS(0.32)
    0.7426521
-->X = TvsS(0.42)
    0.8659525
-->X = TvsS(0.43)
    0.8755403
-->X = TvsS(0.44)
    0.8847004
-->X = TvsS(0.45)
    0.8934414
-->X = TvsS(0.46)
    0.9017061
```



Single-phase induction motors :

note: ECE 331 - Lab on Single Phase Induction Motors pushed back to next week (March 11th)

4) Explain how a 3-phase induction motor is able to keep running when a phase is lost.

Once the motor is spinning, the slip for the forward and reverse rotating fields are no longer identical. This results in a net torque induced in the motor.

5) Explain why this same 3-phase motor won't start once it stops.

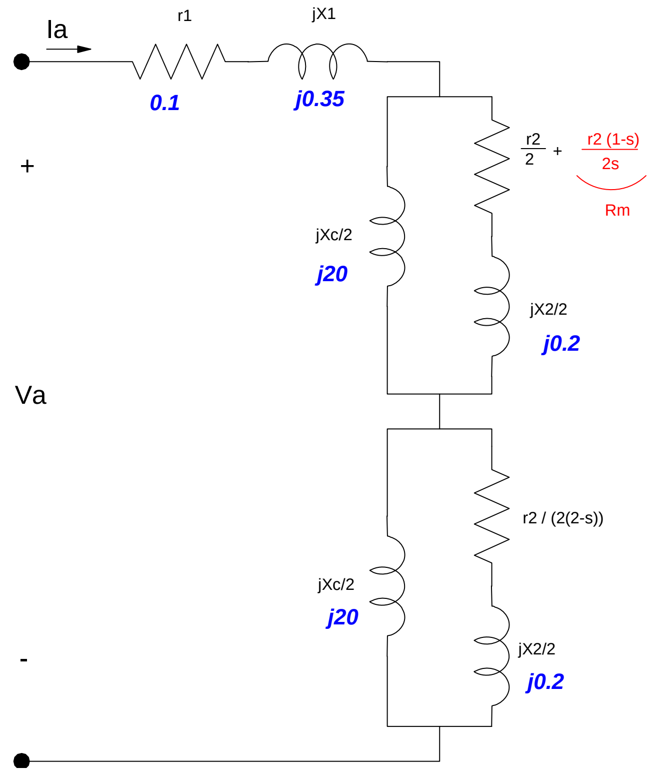
When stopped, the slip for the forward and reverse rotating fields are identical. The induced torques are equal and opposite, resultin in no net torque.

6) Using the following data data, give the results for a short-circuit and open-circuit test for a single-phase induction motor (same as homework #4 but for single phase). Assume a line-to-neutral voltage VLN = 120V

r1 = 0.1 Ohm, x1 = 0.35 Ohms

r2 = 0.12 Ohms x2 = 0.40 Ohms

xc = 40 Ohms



DC Test:

Za = 0.1 Ohm

Locked Rotor Test (s = 1)

$$Z_a = (0.1 + j0.35) + (j20||(0.06 + j0.2))) + (j20||(0.06 + j0.2))$$

$$Z_a = (0.1 + j0.35) + (0.0588 + j0.1982) + (0.0588 + j0.1982)$$

$$Z_a = 0.2176 + j0.7464$$

$$V_a = 120V$$

$$I_a = \frac{V_a}{Z_a} = 154.3\angle -73.75^0$$ (bad! you burn out motors if you lock the rotor at rated voltage)

$$pf = \cos(-73.75^0) = 0.28 \text{ lagging}$$

No-Load Test (s = 0)

$$Z_a = (0.1 + j0.35) + (j20||(\infty + j0.2))) + (j20||(0.03 + j0.2))$$

$$Z_a = (0.1 + j0.35) + (j20) + (j20||(0.0294 + j0.1981))$$

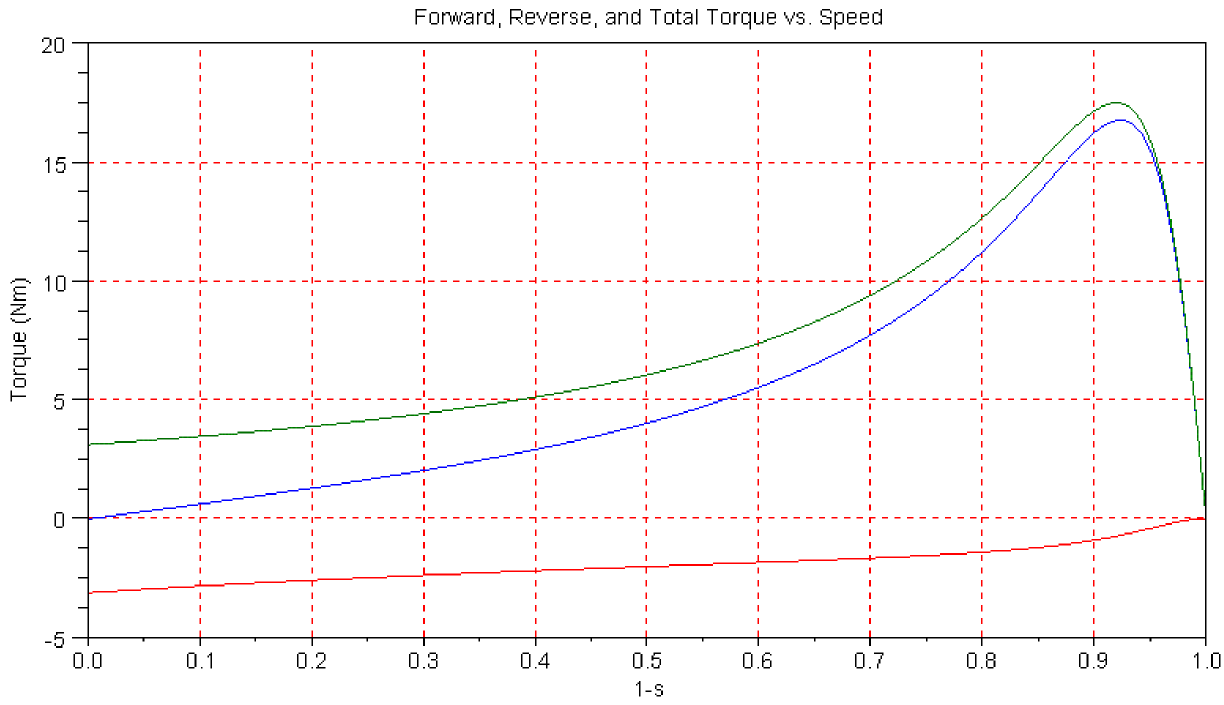
$$Z_a = 0.1294 + j20.55$$

$$V_a = 120V$$

$$I_a = \frac{V_a}{Z_a} = 5.84\angle -89.64^0$$

$$pf = \cos(-89.64^0) = 0.0063 \text{ lagging}$$

7) Determine and plot the torque vs. speed relationship for this motor.



The torque produced by Rm1 (forward rotating field) is in green (top curve)

The torque produced by Rm2 (reverse rotating field) is om red (bottom curve - it's negative and opposes the green line)

The total torque is in blue (center line). Note that at speed = 0, the torques cancel.