**EE 559 Homework #1**
**Due Monday 2/3/2014**

1. Consider a 6-pole induction generator with line-line voltage of 220 volts, and the below data.

   $R_1$=0.294 Ω    $X'_2$=0.209 Ω
   $X_1$=0.503 Ω    $R'_2$=0.061 Ω
   $R_C$=1000 Ω
   $X_m$=13.25 Ω

   In the notes, we showed how to compute the torque for f=60Hz, $\Omega_m$=130 rad/sec, using a circuit analysis approach based on current division. Repeat this example using the circuit analysis approach based on the Thevenin equivalent. Plot the torque-speed characteristic for f=60 Hz, for $\Omega_m$=0 to $\Omega_m$= $\Omega_S$=125.664 rad/sec to $\Omega_m$=2$\Omega_S$=251.328 rad/sec.

**Solution**:

The speed $\Omega_s$ is given by

$$\Omega_s = 2\pi f/(p/2) = 2\pi(60)/(6/2) = 125.664 \qquad rad/\sec$$

We develop the speed-torque characteristic using the following Matlab code.

```
v1= 220/sqrt(3);
r1=0.294;
x1=0.503;
rc= 1000;
xm=13.25;
xp2=0.209;
rp2=0.0610;
ows=125.67;
% Compute thevenin
parameters.
zb=(rc*i*xm)/(rc+i*xm);
za=r1+i*x1;
vth=abs(v1*zb/(za+zb));
zth=za*zb/(za+zb);
```

```
rth=real(zth);
xth=imag(zth);
% Mechanical speed range
owm1=[0*k*ows:1:2*k*ows];
% Torque equation components.
num=3*(vth^2)*rp2;
den1=ows*(1-owm1 /(k*ows));
den2=(rth+rp2./(1-owm1/(k*ows))).^2;
den3=(xth+xp2)^2;
% Compute torque
T1=num ./ (den1.*(den2+den3));
plot(owm1,T1)
grid
```

The above Matlab code results in the speed-torque relationship shown in Fig. 1 below.

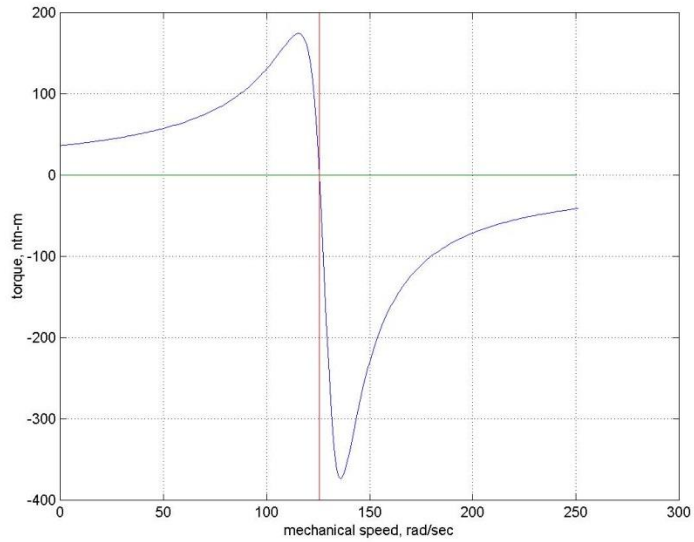


Fig. 1

We observe from Fig. 1 that

- Motor operation is from $\Omega_m$=0 to $\Omega_m$= $\Omega_S$=125.664 rad/sec; this corresponds to positive slip.
- Generator operation is from $\Omega_m$=$\Omega_S$=125.664 rad/sec to $\Omega$=2$\Omega_S$=251.328 rad/sec; this corresponds to negative slip.
- The developed torque for motor operation is positive and for generator operation is negative.
- The maximum developed torque for motor operation is about half of the maximum developed torque for generator operation. The reason for this can be seen in the torque equation (below) where the slip, when negative (generator operation), results in a torque expression denominator that is smaller than when the slip is positive (motor operation).

$$T = \frac{3{V_{th}}^2 R_2'}{(s\omega_s)\left[\left(R_{th} + \frac{R_2'}{s}\right)^2 + (X_{th} + X_2')^2\right]}$$

2. Read the notes and watch the video posted here:
    - Notes:
    - Video:

    Identify, from the video, one thing that you learned about each of the following subsystems:

    a. Yaw
    b. Pitch
    c. Drivetrain
    d. Generator
    e. Power system interconnection
    f. SCADA