The University of Connecticut **Fall 2012**
Dept. of ECE **KRP**

ECE 6095
Problem Set # 2
(Due September 18, 2012)
(Homework can be done in teams of two students. Use MATLAB when necessary)

1. In this problem, we go through a step-by-step process for computing the torque and efficiency of an induction motor. Consider the equivalent circuit of a 460-V, 25-hp[1], 60 Hz, four-pole, Y-connected induction motor shown in Figure 1 with the impedances parameters in ohms per phase referred to the stator circuit as follows:

$$R_1 = 0.641\Omega,\quad R_2 = 0.332\Omega$$
$$X_1 = 1.106\ \Omega,\ X_2 = 0.464\ \Omega,\ X_M = 26.3\ \Omega$$

The total frictional and rotational losses, P_{FR}, are 1100 W and are assumed to be constant. The core loss is lumped in with the rotational losses.

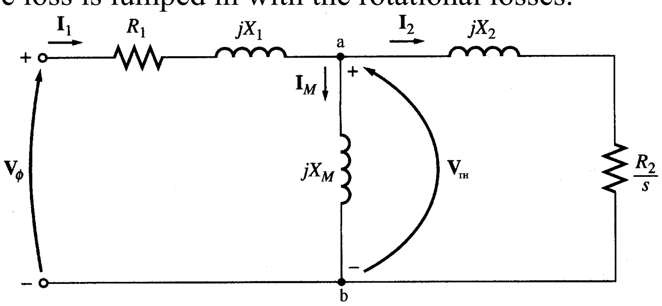


Figure 1: Equivalent Circuit of an Induction Motor

Find the synchronous speed in rpm, n_s and radian frequency, ω_s. For a rotor slip of 2.2 percent at the rated voltage and rated frequency, find the motor's (a) Speed in rpm, n_m and radian frequency, ω_m; (b) Stator current, I_1 (c) Power factor (cosine of the angle, θ of stator current, I_1), (d) Input power, $P_{in} = \sqrt{3}V_\phi I_1 \cos\theta$, (e) stator core losses, $P_{SCL} = 3I_1^2 R_1$, (f) air gap power, $P_{AG} = P_{in} - P_{SCL}$, (g) Converted power, P_{conv} = (1-s) P_{AG} , where s is the slip, (h) output power, $P_{out} = P_{conv} - P_{FR}$, (i) efficiency, $\eta = P_{out} / P_{in}$ and (j) output torque, $T_{out} = \dfrac{P_{out}}{\omega_m}$.

2. (Background) Show that for a continuous state variable feedback system

$$\dot{\underline{x}}(t) = A\underline{x}(t) + B\underline{u}(t), \quad \underline{u}(t) = K_r \underline{r}(t) - K_c \underline{x}(t)$$

the loop gain is given by $LG(s) = K_c(sI - A)^{-1}B.$ For the single input system, if

$$A = \begin{bmatrix} 1 & 1 \\ -3 & 0 \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix} \quad K_c = \begin{bmatrix} \alpha & 3 \end{bmatrix}$$

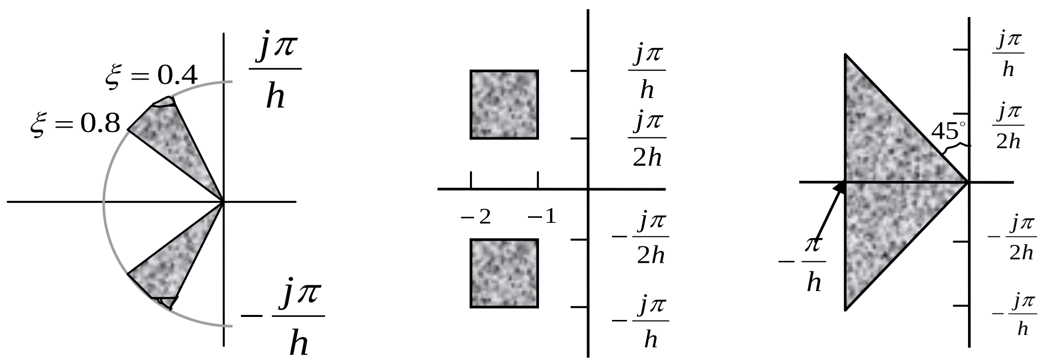
[1] 1hp = 746 watts

for what range of α is the closed-loop system stable? For α = 2 what is the crossover frequency ω_c and the phase margin ϕ_m of the closed-loop system?

3. What are the points in the *z*-plane that correspond to the following points in the *s*-plane when $h = 0.628$?

   (a) $s = -2$ (b) $s = -8$ (c) $s = 1$
   (d) $s = -2 + j2$ (e) $s = -2 + j7$ (f) $s = -j5$
   (g) What point(s) in the s-plane coorespond to $z = -0.5$?

4. What region in the z-plane corresponds to the following regions in the s-plane $z = e^{sh}$ when h = 0.25sec



(a) (b) (c)

5. Consider the all pass filter $H_{ap}(z) = \dfrac{1-az}{z-a}; |a|<1$ (poles and zeros are mirror images around unit circle). These will be useful in loop shaping. By evaluating $H(e^{j\omega})H(e^{-j\omega})$ *or* $H(z)H(z^{-1})$, show that the magnitude is one. Determine an expression for the phase angle of $H_{ap}(z)$.