EE321 Exam 4
Spring 2011

Notes**: You must show work for credit on Problems 1-3.**

Good luck!

Handy Facts

$$\mu_0 = 4\pi 10^{-7} \text{ H/m}$$

Table A-1 Trigonometric Identities

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$
$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$
$$\cos A \cos B = \tfrac{1}{2}[\cos(A+B) + \cos(A-B)]$$
$$\sin A \sin B = \tfrac{1}{2}[\cos(A-B) - \cos(A+B)]$$
$$\sin A \cos B = \tfrac{1}{2}[\sin(A+B) + \sin(A-B)]$$
$$\sin A + \sin B = 2 \sin \tfrac{1}{2}(A+B) \cos \tfrac{1}{2}(A-B)$$
$$\sin A - \sin B = 2 \sin \tfrac{1}{2}(A-B) \cos \tfrac{1}{2}(A+B)$$
$$\cos A + \cos B = 2 \cos \tfrac{1}{2}(A+B) \cos \tfrac{1}{2}(A-B)$$
$$\cos A - \cos B = -2 \sin \tfrac{1}{2}(A+B) \sin \tfrac{1}{2}(A-B)$$
$$\sin 2A = 2 \sin A \cos A$$
$$\cos 2A = 2\cos^2 A - 1 = 1 - 2\sin^2 A = \cos^2 A - \sin^2 A$$
$$\sin \tfrac{1}{2}A = \sqrt{\tfrac{1}{2}(1 - \cos A)} \qquad \cos \tfrac{1}{2}A = \sqrt{\tfrac{1}{2}(1 + \cos A)}$$
$$\sin^2 A = \tfrac{1}{2}(1 - \cos 2A) \qquad \cos^2 A = \tfrac{1}{2}(1 + \cos 2A)$$
$$\sin x = \frac{e^{jx} - e^{-jx}}{2j} \qquad \cos x = \frac{e^{jx} + e^{-jx}}{2} \qquad e^{jx} = \cos x + j \sin x$$
$$A \cos(\omega t + \phi_1) + B \cos(\omega t + \phi_2) = C \cos(\omega t + \phi_3)$$

where

$$C = \sqrt{A^2 + B^2 - 2AB \cos(\phi_2 - \phi_1)}$$
$$\phi_3 = \tan^{-1}\left[\frac{A \sin \phi_1 + B \sin \phi_2}{A \cos \phi_1 + B \cos \phi_2}\right]$$
$$\sin(\omega t + \phi) = \cos\left(\omega t + \phi - \frac{\pi}{2}\right)$$

Taken from, *Continuous and Discrete Signal and Systems Analysis, 2nd Edition,* by McGillem & Cooper, 1984, CBS College Publishing, and one heck of a good book.

1.) 25 pts. Consider a single-phase transformer. The primary resistance is 1 Ω, the primary leakage inductance is 10 mH, the referred secondary winding resistance is 1 Ω, the referred secondary leakage inductance is 10 mH, and the primary-to-secondary turns ratio is 2. The magnetizing inductance may be considered to be infinite. A sinusoidal voltage of 100 V rms at 100 rad/s (note radian frequency) is applied to the primary and a resistance of 1 Ω (physical, not referred) is placed across the secondary winding. What is the rms value of the actual voltage across the secondary winding?

2.) 25 pts. Consider the operation of a 4-pole induction machine. Suppose

$$i_{ar} = 100\sqrt{2}\cos(100t - 2)$$
$$i_{br} = -100\sqrt{2}\sin(100t - 2)$$

The stator to rotor turns ratio is 4. The rotor position is given by

$$\theta_{rm} = 200t + 5 \text{ (radians)}$$

Find the following (*i*) $\tilde{I}_{ar}$ and $\tilde{I}_{br}$, (*ii*) i'_{ar} and i'_{br} (as functions of time), (*iii*) i'^{s}_{qr} and i'^{s}_{dr}, (*iv*) $\tilde{I}'^{s}_{qr}$ and $\tilde{I}'^{s}_{dr}$, and (*v*) the absolute value of the radian frequency of the stator currents. Recall that

$$\mathbf{K}_r^s = \begin{bmatrix} \cos\theta_r & -\sin\theta_r \\ -\sin\theta_r & -\cos\theta_r \end{bmatrix}$$

(more paper follows)

Extra Paper for Problem 2

3.) 25 pts. Consider a 3-phase wye-connected induction machine. The stator resistance and stator and rotor leakage inductances are negligible. The machine has $L_M = 30$ mH and $r_r^{'} = 30$ mΩ. The machine is controlled such that the rms phase current is 50 A, and that the radian slip frequency is 1 rad/s. The machine has 4 poles. Under these conditions, what is the electromagnetic torque? If the speed of the machine is 2000 rpm, what is the rms line-to-line voltage?

(more paper follows)

Extra Paper for Problem 3

4.) 3 pts. Name three commonly used tests to characterize induction machine parameters.

5.) 2 pts. Are wind turbine induction generators doubly or singly fed?

6.) 3 pts. Name two non-idealities that cause error in our induction motor models.

7.) 0 pts. Which popular rock band has a song whose lyrics focus on induction machines?

8.) 2 pts. Of the induction motor models we studied, which are the two most used?

9.) 2 pts. Name an attractive feature of volts-per-hertz control.

10.) 2 pts. Name an attractive feature of maximum-torque-per-amp control.

11.) 2 pts. What is unattractive feature of maximum-torque-per-amp control.

12.) 2 pts. Why did we refer the rotor variables to the stator?

13.) 2 pts. Why did we make a transformation to qd variables?

14.) 2 pts. How many phases (in reality) do most single-phase machines haves?

15.) 3 pts. Name three types of induction machines.