Problems
Induction and Synchronous Motor Drives

Module EE5303 – Electrical Machine Drive and Special Machines
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Problem 1

A speed control range from 0.45 to 0.8 times full load speed is desired for a pump drive system. An induction motor is chosen with the following parameters

150 hp, 460 V, 3 phase, 60 Hz, star-connected, $R_s = 0.03\ \Omega$, $R_r' = 0.22\ \Omega$, $X_m = 10\ \Omega$, $X_{ls} = 0.1\ \Omega$, $X_{lr}' = 0.12\ \Omega$, full load slip = 0.1477, friction and windage losses = $(0.01\ \omega_m + 0.0005\ \omega_m^2)$ N.m

The pump load constant, C, is 0.027 N.m/(rad/sec)^2. Find the range of the stator voltage and current that must be given by the control system of the three phase AC voltage regulator to achieve the desired speed variations with stator voltage control.

Problem 2

A 3-phase, Y-connected, 60 Hz, 4-pole induction motor has the following parameters:

$$R_s = R_r' = 0.024\ \Omega,\ X_{ls} = X_{lr}' = 0.12\ \Omega$$

The motor is controlled by the variable frequency control with a constant *V/f* ratio. For an operating frequency of 12 Hz, calculate

1. The breakdown torque as a ratio of its value at the rated frequency for both motoring and braking.
2. The starting torque and rotor current in terms of their values at the rated frequency.

Problem 3

A 400 Y, 50 Hz, 6-pole, 960 rpm, Y-connected induction motor has the following parameters per phase referred to the stator:

$$R_s = 0.4\ \Omega,\ R_r' = 0.2\ \Omega,\ X_{ls} = X_{lr}' = 1.5\ \Omega,\ X_m = 30\ \Omega$$

The motor is controlled by variable frequency control at a constant flux of rated value.

1. Calculate the motor speed and the stator current at half the rated torque and 25 Hz.
2. Solve for part 1 assuming the speed-torque curves to be straight lines for $\sigma < \sigma_{max}$
3. Calculate the frequency, the stator current, and voltage at the rated braking torque and 800 rpm.

Problem 4

A 3-phase, 460 V, 60 Hz, 1164 rpm, Y-connected, wound-rotor induction motor has the following parameters:

$$R_s = 0.4\ \Omega,\ R_r' = 0.6\ \Omega,\ X_{ls} = X_{lr}' = 1.8\ \Omega,\ X_m = 40\ \Omega,\ \text{stator to rotor turns ratio is 2.5}$$

The motor speed is controlled by static rotor resistance control. Fi1ter resistance is 0.02 Ω and the externa resistance is chosen such that at $\delta = 0$, the breakdown torque is obtained at standstill.

1. Ca1cu1ate the va1ue of the external resistance.
2. Ca1culate δ for a speed of 960 rpm at 1.5 times the rated torque.
3. Ca1culate the speed for $\delta = 0.6$ and l.5 times the rated torque.

Neglect friction and windage.

Problem 5

The motor of problem 3 is now controlled by a static Kramer drive. The drive has been designed to provide speed control up to 50 percent of the synchronous speed. The maximum value of the firing angle is 170° and $R_f = 0.02$ Ω.

1. Calculate "a_T".
2. Calculate the torque and power factor for $\alpha = 120°$ and 720 rpm.
3. Calculate α for the rated torque and 720 rpm.

Problem 6

A 3-phase 6600 V, 6 pole, 60 Hz, 1100 kW, Y-connected wound-field synchronous motor has the following parameters:

$$X_m = 30\ \Omega,\ X_{ls} = 6\ \Omega,\ R_s, = 1.2\ \Omega,\ \text{field winding resistance} = 5\ \Omega,\ n = 2$$

When operating at the rated power and unity power factor, calculate

1. The field current and torque angle at full load.
2. The pull-out torque.
3. The power factor, armature current, and efficiency at half the rated torque and rated field current.
4. The field current to get unity power factor at half the rated torque.

Neglect friction, windage, and core loss.

Problem 7

The machine of problem 6 is now controlled from a variable frequency source. The V/f ratio is maintained constant up to base speed. Calculate

1. The armature current, torque angle, and power factor at full-load torque, half the rated speed, and the rated field current.
2. The armature current and power factor at half the rated speed, half full-load torque, and the rated field current.
3. The torque and field current for the rated armature current, 1500 rpm, and the unity power factor.