PP1

TECHNICAL UNIVERSITY OF MOMBASA

SCHOOL OF ENGINEERING AND TECHNOLOGY

ELECTRICAL ENGINEERING DEPARTMENT

UNIVERSITY EXAMINATION FOR:

DEGREE

TEE 4419: ELECTRICAL MACHINE DRIVES

END OF SEMESTER EXAMINATION

SERIES: MAY 2025

TIME: 2 HOURS

DATE:

Instructions: *Attempt **question one** and any other **two** questions.*
Show all working in a neat and legible manner

QUESTION ONE: Compulsory [30 Marks]

a) Using a well labled diagram explain the effects of rotor resistance on different torque requirements. **[3 MARKS]**

b) Highlight and explain three classes of squirrel cage motors **[3 MARKS]**

c) The speed of a 20hp, 300V, 1800rpm separately excited dc motor is controlled by a three – phase full converter drive. The field current is also controlled by a three-phase full converter and is set to the maximum possible value. The ac input into a three phase Y-connected 208V 60Hz supply. The armature resistance R_a = 0.25Ω, the field resistance R_f = 245Ω, and the motor voltage constant is K_v = 1.2V/A rad/s. The armature and field currents can be assumed to be continuous and ripple free. The viscous friction is negligible. Determine:

i) The delay angle of the armature converter α_a if the motor supplies the rated power at the rated speed . **[3Marks]**

ii) The no load speed if the delay angle is the same as in (a) and the armature current at no load is 10% of the rated value. **[3Marks]**

iii) Find the speed regulation. **[2Marks]**

d) Explain why a braking resistor is often inserted across the DC–Link of the converters.

[1Marks]

e) Draw the converter topology which will allow variable speed operation of the three-phase induction motor from a fixed main supply. **[2Marks]**

f) By use of a well labelled diagram, show the characteristics of a separately excited dc motors (label your diagram appropriately). **[3Marks]**

g) Show the four quadrants of operation of a DC motor on a Torque vs Speed plane. On your diagram, show how V_a, I_a and E_a are manipulated to achieve operation of the motor in each of the four quadrants. **[3Marks]**

h) The speed of a separately excited dc motor is controlled by a single-phase full wave converter. The field circuit is also controlled by a full converter and the field current is set to the maximum possible value. The ac supply voltage to the armature and field converter is one phase, 440V, 60Hz. The armature resistance R_a=0.25 Ohm, the field resistance is R_f=175 Ohm, and the motor voltage constant K_v=1.4V/A rad/s. The armature current corresponding to the load demand I_a=45A. If the delay angle of the armature converter is α_a=60° and the armature current I_a=45A, determine:

i) The torque developed by the motor T_d. **[3Marks]**

ii) The speed ω. **[2Marks]**

iii) Input PF of the drive. **[2Marks]**

QUESTION TWO [20 Marks]

a) The speed of a 125hp, 600V, 1800rpm, separately excited dc motor is controlled by a 3Φ (Three Phase) full converter. The converter is operated from a 3Φ, 480V, 60Hz supply. The rated armature current of the motor is 165A. The motor parameters are R_a=0.0874Ohms, L_a=6.5mH, and KΦ=0.33V/rpm. The converter and ac supply are assumed to be ideal.

i) Find the no load speed at firing angles α=0deg, and α=30deg, assume that, at no load, the armature current is 10% of the rated current and is continuous

ii) Find the firing angle to obtain the rated speed of 1800rpm at rated motor current

iii) Compute the speed regulation for the firing angle obtained in part (ii) above taking currents 10% of the rated. **[14Marks]**

b) The speed of a separately excited dc motor is controlled by a chopper. The dc supply is 120V, the armature circuit resistance $R_a = 0.5\,Ohms$, the armature circuit inductance $L_a = 20\,mH$, and

the motor constant is KΦ=0.05V/rpm. The motor drives a constant-torque load requiring an average current of 20A. Assume that the motor current is continuous: Determine,

i) Range of speed control

ii) Range of duty cycle **[8Marks]**

c) Show that if the slip frequency is kept constant, the torque developed by an induction machine is proportional to the square of the input current. **[3 MARKS]**

d) Show that if the slip frequency is kept constant, the torque developed by an induction machine is proportional to the square of the input current. **[3 MARKS]**

QUESTION THREE [20 Marks]

a) The speed of a 10hp, 220V, 1200rpm separately excited dc motor is controlled by a single-phase full converter, the rated armature current is 40A. the armature resistance $R_a = 0.25\,Ohms$ and the inductance $L_a = 10\,mH$. The ac supply voltage is KΦ=0.18V/rpm. Assume that the motor current is continuous and ripple free, for a firing angle of 30deg, and rated motor current, determine the:

i) Speed of the motor **[3Marks]**

ii) Motor torque **[3Marks]**

iii) Power of the motor **[3Marks]**

b) A 230V DC shunt motor draws 25A while running at a speed of 600rpm. Armature resistance is 0.1 Ohm and the field resistance is 115 Ohm. Total rotational loss is 750Watts. Calculate:

i) Armature torque

ii) Overall efficiency of the motor **[5Marks]**

c) Explain the following methods of induction motor starting **[6 MARKS]**

i. One stop starting auto transformer

ii. Star delta starting

iii. Solid state voltage controller for starting

QUESTION FOUR [20 Marks]

a) A separately excited dc motor has the following parameters

$R_a = 0.5\,ohm, \quad L_a \cong 0 \quad B \cong 0$

The motor generates an open circuit armature voltage of 220V at 2000rpm and with a field current of 1.0Ampere. The motor drives a constant load torque $T_L = 25\,N.m$ The combined inertia of the motor and load is J=2.5kg.m^2. With afield current $I_f = 1.0\,A$, The armature currents are connected to a 220V dc source.

i) Derive an expression for speed (w_m) and the armature current (i_a) as a function of time. **[10Marks]**

ii) Determine the steady-state values of the speed and armature current, **[4Marks]**

b) A three-phase source of variable frequency is required for an experiment. The frequency changer system is as shown in Fig. E5.7. The induction machine is a three-phase, six-pole, Wound-rotor type whose stator terminals are connected to a three-phase, 460 volt, 60 Hz supply. The variable-frequency output is obtained from the rotor terminals. The frequency is to be controlled over the range 15_120 Hz. **[6 MARKS]**

i. Determine the speed in rpm of the system to give 15 Hz and 120 Hz.

ii. If the open-circuit rotor voltage is 240 volts when the rotor is at standstill, determine the rotor voltage available on open circuit with 15 Hz and 120 Hz.

iii. If all the losses in the machine are neglected, what fraction of the output power is supplied by the ac supply, and what fraction is supplied by the dc machine at 15 Hz and 120 Hz?

QUESTION FIVE [20 Marks]

a) A 150kW, 460V, 3-phase 3520r/min, 60Hz induction motor has a locked-rotor torque of 600N.m and a locked rotor current of 1400A. Three resistors are connected in series with the line so as to reduce the voltage across the motor to 0.65p.u.

Calculate:

i) The apparent power absorbed by the motor under full-voltage, locked conditions. **[2Marks]**

ii) The apparent power absorbed by the motor when the resistors are in the circuit. **[3Marks]**

iii) The apparent power drawn from the line, with the resistors in the circuit, **[3Marks]**

iv) The locked-rotor torque developed by the motor, **[2Marks]**

b) A standard 3-phase, 10hp, 575V, 1750r/min, 60Hz NEMA class D squirrel cage Induction motor develops a torque of 110 N.m at a speed of 1440r/min. If the motor is excited at a frequency of 25Hz, Calculate:

i) The squirrel voltage to maintain the same flux in the machine **[2Marks]**

ii) The new speed at 110N.m **[3Marks]**

c) A three phase 460V, 4 pole Y connected induction motor has the following equivalent circuit parameters: RS=0.42Ω, $Rf^{'} = 0.23\ \Omega$, $X1 = X^{1} = 0.82\ \Omega$, $XM = 22\ \Omega$. The no load loss which is p no load =60W,may be assumed constant. The rotor speed is 1750RPM.

[5 MARKS]

i. Draw the equivalent circuit
ii. Determine the synchronous speed
iii. Slip
iv. Input current
v. Input power input PF of supply