University of Wollongong

School of Electrical, Computer and Telecommunications Engineering

ECTE323 Power Engineering 2

Mid-term Test 2008

Time: 50 Minutes

Attempt any ONE (1) out of TWO (2) questions.

Question 1 [20 Marks]

Part (a): [2 marks]
Why the direction of rotation of the rotor of an ac motor changes if two of the three phases of supply voltage are interchanged (or phase-sequence of the supply is changed)?

Answer:
The direction of rotation of revolving field of the machine will change if phase-sequence is changed and rotor will follow the rotation of the revolving field.

Part (b): [2 marks]
Why are the brushes of a dc machine always placed at the neutral zones?

Answer:
Placing a brush on commutator of a dc machine momentarily short-circuits a coil of the armature. Neutral zones are those places on the surface of the armature where the flux density is zero. Voltage induced in the coils at neutral zones will be zero. Therefore, brushes are always placed at the neutral positions on the commutator so that they short-circuit those coils in which the induced voltage is momentarily zero.

Part (c): [6 marks]
A separate excited dc generator turning at 1400 r/min produces an induced voltage of 127 V. The armature resistance is 2 Ω and the machine delivers a current of 12 A. Draw the circuit diagram of the generator and calculate the following:

(i) The terminal voltage,
(ii) The heat dissipated in the armature, and
(iii) The breaking torque exerted by the armature.

(i) The terminal voltage

$E = E_0 - IR_a = 127 - 12 \times 2 = 103\,V$

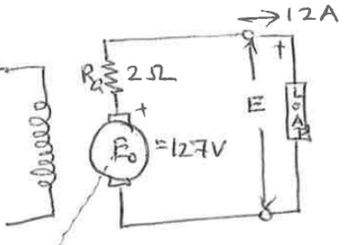
(ii) The heat dissipated in the armature

$= I^2 R_a = 12^2 \times 2 = 288\,W$

(iii) The braking torque is

$T = \frac{P}{\omega} = \frac{P}{2\pi n/60} = 9.55\frac{P}{n} = \frac{9.55 \times 1524}{1400} = 10.4\ N\text{-}m$

The power developed, $P = E_0 I = 127 \times 12 = 1524\,W$



Part (d): [6 marks]

The motor shown in Fig.Q1(d) is a cumulative compound motor and has 1200 turns on the shunt winding and 25 turns on the series winding, per pole. The shunt field has a total resistance of 115 Ω, and the nominal armature current is 23 A. If the motor is connected to a 230 V line, show the direction of flux in the diagram and calculate the following:

(i) The mmf per pole at full-load, and

(ii) The mmf at no load.

Draw the connection diagram of a differential compound motor that has the same parameters of the cumulative compound motor given in Fig.Q1(d). If the motor has the same armature current and applied voltage, show the direction of flux in the diagram and calculate the following:

(iii) The mmf per pole at full-load, and

(iv) The mmf at no load.

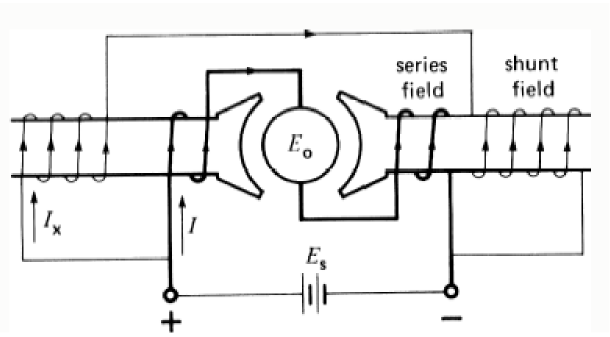
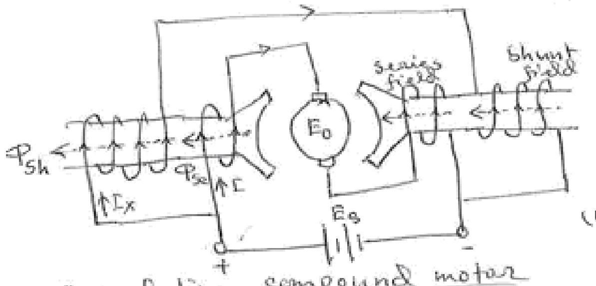
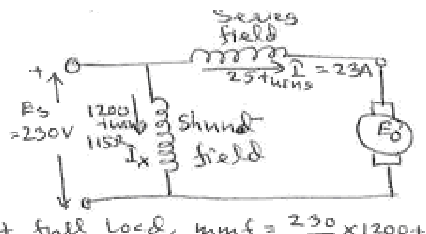


Fig.Q1(d): Connection diagram of a dc compound motor



Cumulative compound motor



(i) At full load, mmf $= \frac{230}{115} \times 1200 + 25 \times 23$

$= 2400 + 575$

$= 2975$ At

(ii) At no-load, mmf $= 2400 + 0$

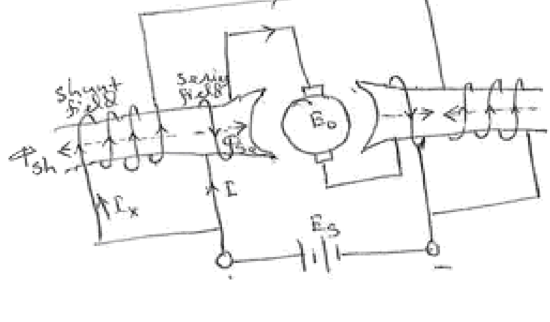
$= 2400$ At

(iii) At full load, mmf $= 2400 - 575$

$= 1825$ At

(iv) At no-load, mmf $= 2400 - 0$

$= 2400$ At



Part (e): [4 marks]

The terminals of each of the three single-phase transformers shown in Fig.Q1(e) have polarity marks H_1, H_2, X_1, X_2. Make schematic drawing of delta-wye connection of transformers for transferring power in a three-phase system, where primary side (delta connection) is connected to a wye-connected generator and secondary (wye-connection) is connected to a wye-connected (three-phase) load. Show connection details for generator, transformers and load in your drawing.

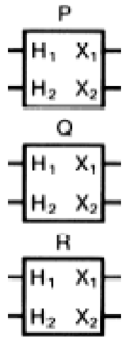
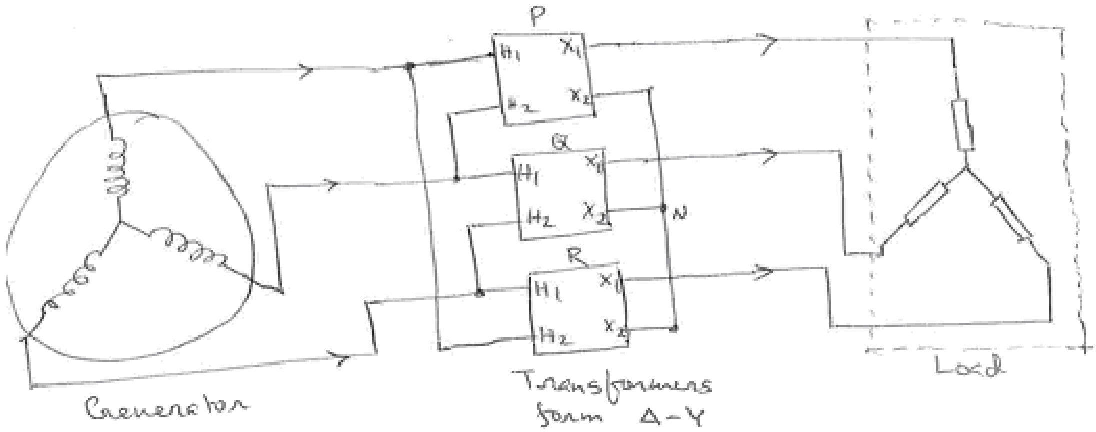


Fig.Q1(e): Three - single phase transformers, P, Q and R



Question 2 [20 Marks]

Part (a) [2 marks]

A three-phase mains supplied wound rotor induction motor produces a maximum torque of 100 Nm when the external rotor resistance is 3 Ω. When the rotor resistance is increased to 6 Ω, what maximum torque is obtainable?

Answer:

100Nm (i.e. the rotor resistance does not change maximum torque)

Part (b) [6 marks]

A 15 kW, 4 poles, 400 V, 50 Hz, star connected, three-phase induction motor runs at 1440 rpm on full load. The stator copper losses are 215 W, and the rotational losses are 350 W at this speed.

(i) Determine the gross mechanical power developed by the motor at rated speed and the power transferred across the airgap.

(ii) Determine the rotor copper losses at rated speed.

(iii) Determine the total input power and the efficiency of the motor.

Answer:

(i)

$P_m = P_{out} + P_{rot}$
$= 15000 + 350$
$= 15350W$

$P_g = P_m / (1-s)$
$= 15350 / (1 – 0.04)$
$= 15990W$

(ii)

$P_{rcl} = P_g - P_m$ or $P_{rcl} = sP_g$

$= 15990 - 15350$

$= 640$

(iii)

$P_{in} = P_g + P_{scl}$

$= 15990 + 215$

$= 16205W$

$\eta = P_{out} / P_{in}$

$= 15000 / 16205$

$= 92.6\%$

Part (c) [2 marks]

What constraints does an infinite bus impose on a generator paralleled with it? What conditions must be met before a generator can be connected to a three-phase system?

Answer:
Constraints imposed by an infinite bus are voltage and frequency.

Conditions to be satisfied are:
Voltage magnitudes should be same,
Voltages should be in phase
Frequency should be same and
Phase sequence should be same

Part (d) [5 marks]

A test taken on the 500 MVA alternator yields the following results:

Open-circuit line voltage is 15 kV for a dc exciting current of 1400 A.

Using the same dc current, with the armature short-circuited the resulting ac line current is 21000 A.

Calculate

(a) The base impedance of the generator per phase,
(b) The value of the synchronous reactance,
(c) The per-unit value of X_s,
(d) The short-circuit ratio.

Answer:

(a) The base impedance $Z_B = \frac{(kV)^2}{MVA} = \frac{(15\,kV)^2}{500\,MVA} = 0.45\,\Omega$

(b) $E_{LN} = \frac{15000V}{\sqrt{3}} = 8660V$ $\quad X_s = \frac{8660V}{21000A} = 0.412\,\Omega$

(c) $X_{s\,(p.u.)} = \frac{0.412}{0.45} = 0.916$ p.u.

(d) Short-circuit ratio $= \frac{1}{X_{s\,(p.u.)}} = \frac{1}{0.916} = 1.09$.

Part (e) [5 marks]

A 20 MW, 11 kV, 1500 rpm, three-phase, star connected synchronous generator connected to an infinite bus has a synchronous reactance of 5 Ω per phase. The generator is driven by a steam turbine. If the excitation voltage is 8 kV per phase, and the system voltage is 11 kV line to line, calculate the following:

(i) The total real power delivered to the grid by the generator when the electrical torque angle is 20^0?
(ii) How would you adjust the amount of real power delivered to the system by the generator?
(iii) What is the peak power that the generator can deliver before it losses synchronism?

Answer:

(i)

$P = 3\ V\ E \sin\delta / X_s$

$= 3 \times 6350.85 \times 8000 \times \sin 20° / 5$

$= 10.43MW$

(ii)

By controlling the flow of steam/water etc to prime mover (turbine)

(iii)

$P = 3\ V\ E \sin\delta / X_s$

$= 3 \times 6350.85 \times 8000 \times \sin 90° / 5$

$= 30.48MW$