M.E. (Electrical) 1st Semester Supplementary Examination,2013

Generalised Theory of Electrical Machines

(EE-903)

Time: 3 hours **Full Marks : 70**

(i)The questions are of equal value.
(ii) Answer any 3 questions taking ***2 from Group-A and 1 from Group-B***
(iii) Use graph paper(s) if required.
(iv) All symbols have their usual significance.

Group A

1. a) Explain, with any derivation as may be necessary, how a rotating commutator winding may be represented as an equivalent pseudo-stationary coil along the brush axis, and highlight with proper logic the features of such a coil.
b) What is Kron's primitive machine? Derive the general voltage and torque equations of such a primitive machine containing appropriate d-q coils on both stator and rotor members. Show in details how to develop a general impedance matrix incorporating terms corresponding to resistance, self and mutual inductances and the effect of rotational voltages. Also derive the terms of the [G] matrix with clear explanation of the terms.
c) Extend the above case to obtain the usual expressions of voltages and currents and torque developed in a separately excited dc motor. (5+13+5)=23

2. (a) What do you mean by 3-phase to 2-phase transformation as applied to a three phase balanced rotor winding rotating at a speed of ω_r? Derive in details with clear justification of the manipulations done. Clearly explain the role of the "γ-axis" coil required in the above transformation.
(b) Explain slip-ring to commutator transformation as applied to a system of balanced two phase quadrature coils mounted on electric machine rotor rotating at a speed of ω_r with detailed analytical derivation. (14+9) = 23

3. (a) Obtain the d-q axis model for a 3-phase synchronous motor and derive the d-q reference frame voltage equations.
(b) The parameters of a 10 MVA, 11 kV, 3-phase, 10-pole, 50 Hz synchronous motor operating at 0.866 leading p.f. are:

Direct axis synchronous reactance	12 Ω/phase
Quadrature axis synchronous reactance	6 Ω/phase
Resistance	0.5 Ω/phase

For rated current flowing in the armature determine (i) the excitation voltage and rotor angle and (ii) the cylindrical, reluctance and total torque under steady state. Draw the phasor diagram. (10+13)=23

4. (a)Three balanced abc-reference frame sinusoidal currents have a frequency of 50 Hz and an amplitude of 10 A. The same are flowing in three balanced (and mechanically symmetric) distributed coils in the rotor of 3-phase 4-pole machine. Derive the expressions for the $\alpha\beta\gamma$-reference frame currents as functions of time. Plot the abc and $\alpha\beta\gamma$ currents to proper scale.
(b) If the rotor rotates at 1500 rpm find expressions for the $dq\gamma$-reference frame currents and plot the same to scale.
(c) If the rotor rotates at 750 rpm find expressions for the $dq\gamma$-reference frame currents and plot the same.
(d) If the machine rotor coils under some condition is found to have 5A amplitude currents balanced at 25 Hz, with the rotor running at 750 rpm and the $dq\gamma$-reference frame currents are found to be dc then identify, with proper justification, what type of machine this may be?
(e) If the machine rotor coils under some condition is found to have 5A amplitude currents balanced at 25 Hz, with the rotor running at 720 rpm and the $dq\gamma$-reference frame currents are found to be having a frequency of 1Hz then identify, with proper justification, what type of machine this may be?
(9+4+4+3+3) = 23

Group B

5. (a) A d.c. shunt generator is running steadily and develops a constant voltage on no-load. The armature terminals of the shunt generator are suddenly short-circuited. Find the expression to show the nature of variation of both the field current and the armature current with time, taking the instant of short-circuit at t=0. Draw the curves.
(b) A d.c. separately excited generator is running steadily and develops a constant voltage on no-load. If the armature terminals of the generator are suddenly short-circuited, investigate the nature of variation of the armature current with time. (13+10)

6. (a) A d.c. separately excited generator with series field, connected to a constant voltage supply is suddenly short-circuited. Determine the expression for transient armature current.
(b) Discuss the methods to show how the effect of saturation can be taken into account in the analysis of d.c. machine. (13+10)

7. (a) Determine the time of building up of voltage in a saturated exciter at no-load with the help of Froelich's equation.
(b)Find the transfer function of a Ward-Leonard system considering load torque to vary linearly with speed. Hence find the expression for motor speed as a function of time when a d.c. supply is suddenly applied across the generator field winding taking the instant of application of d.c. supply at t=0. Develop the block diagram of the system. (10+13)

M.E. (Electrical)
1st Semester Examination, December 2013

Subject : Generalised Machine Theory

Code No. **EE 903**
Branch: EE
Full Marks : 70

Time : 3 hours

(i) The questions are of equal value.
(ii) Answer any **3** questions taking ***2 from Group A and 1 from Group B***.
(iii) Use graph paper(s) if required.
(iv) All symbols have their usual significance.
(v) Two marks reserved for neatness in each Group.

Group A

1.(a) Starting from 'abc'-reference frame model, obtain the d-q axis model for a 3-phase synchronous motor (SM) and derive the voltage and torque equations. Particularly highlight the transformation of Z_{abc} to $Z_{dq\gamma}$.
(b) What would be the values of currents and voltages in the 's' and 't' coils at steady state and why?
(c) Which transformation matrices are affected by a change of winding phase sequence and why?
(d) A balanced set of 3-phase slip-ring based coils, mounted on a machine rotor are carrying balanced 3-phase 50 Hz currents of 10A. The computed rms values of the 'dqγ 'currents are 12.247A, 0A and 0A dc respectively. The machine is 4-pole machine. The rotor rotates a motor at a speed of N rpm. Evaluate N.
Show details of calculations. (12+3+3+4)

2.(a) On the d-q space-time phasor plane identify the operation of the SM as motor or generator and its excitation status in the different quadrants. Justify through clear logic.
(b) Show through proper construction after relevant analytical derivation, how one can locate the d-q axis components from the conventional phasor diagram of a 3-phase SM operating at lagging p.f.
(c) The parameters of a 1 MVA, 11 kV, 3-phase, 6-pole, 50 Hz SM operating at 0.866 leading p.f. are:

Direct axis synchronous reactance	17 Ω/phase
Quadrature axis synchronous reactance	10 Ω/phase
Resistance	0.8 Ω/phase

For rated current flowing in the armature determine (i) the excitation voltage and rotor angle and (ii) the cylindrical, reluctance and total torque under steady state. Draw the phasor diagram.
(5+7+10)

3.(a) Utilise tenets of generalised theory and use appropriate transformation tools to obtain an appropriate equivalent circuit for a 3-phase induction machine (IM) based on stator reference frame. Also point out how this circuit is identical with the conventional per phase equivalent circuit of the IM. Draw the on-load phasor diagram and identify the D-Q axes on it.
(b) Use small perturbation theory to obtain transient flux linkage and voltage equations for a salient pole SM having damper windings.
(c) Justify why speed has been assumed to be constant in the analysis in part(b) above.
(d) From the derivations of part(b) above obtain the "operational impedance circuits" under transient operation. (10+6+2+4)

4.(a) A balanced set of 3-phase slip-ring based coils, mounted on a machine rotor are carrying balanced 3-phase 50 Hz currents of 10 A. The machine is 6-pole machine. The rotor rotates a motor at a speed of N rpm. Evaluate using results of appropriate transformations (need not derive)

(i) $[i]_{\alpha\beta\gamma}$ and $[i]_{dq\gamma}$ if N = 500 rpm. What is the frequency of the rotor currents as seen by a stator based observer? Justify analytically.

(ii) Plot the waveforms of i_a, i_α, i_β, i_d and i_q with appropriate scaling on the axes. Make all necessary derivations in brief.

(b) What is the essential difference between the stator based d-q reference frame in between SM and IM?

(c) A 4-pole, 3-phase, 50 Hz induction motor with a star connected rotor winding has a standstill slip-ring voltage of 180 V. The rotor resistance and reactance per phase are 0.25Ω and 1.5Ω respectively. Determine,

(i) The torque and rotor phase current at starting,

(ii) The maximum torque, corresponding slip and rotor phase current. Neglect stator series impedance.

(iii)Draw the phasor diagram.

(4+8+2+8)

Group B

5.(a) A d.c.separately excited generator is running steadily and develops a constant voltage on no load. If the armature terminals of the generator are suddenly short-circuited, investigate the nature of variation of the armature current with time.

(b) A d.c. shunt generator is running steadily and develops a constant voltage on no-load. The armature terminals of the shunt generator are suddenly short-circuited. Find the expression to show the nature of variation of both the field current and the armature current with time, taking the instant of short-circuit at t=0. Draw the curves.

(c) A separately excited d.c. generator running at 4500/π r.p.m has the following parameters:

$r_f = 80\Omega$	$L_f = 40H$	$M_f = 0.8H$
$r_a = 0.1\Omega$	$L_a = 0.03H$	

Find (i) the armature induced voltage as a function of time and sketch it if a constant voltage at 160V is suddenly impressed across the field terminal.

(ii) sketch the rise of armature current in part (i) if the armature terminals are initially short- circuited.

(d) Find the transfer function of a Ward-Leonard system considering load torque to vary linearly with speed. Hence find the expression for motor speed as a function of time when a d.c. supply is suddenly applied across the generator field winding taking the instant of application of d.c.supply at t=0. Develop the block diagram of the system.

(6+6+5+5)

6.(a) From the expression of torque and power, find the equations for small changes of a separately excited d.c. motor. Hence find out the condition to check the stability of the system.

(b) Discuss the methods to show how the effect of saturation can be taken into account in the analysis of d.c.machine.

(c) Determine the time of building up of voltage in a saturated exciter at no-load with the help of Froelich's equation.

(d) What is an Amplidyne. Derive the block diagram of an Amplidyne.

(6+5+6+5)