Mansoura University.
Faculty of Engineering.
Electrical Engineering Dept.

First Semester. نظام قديم
Date: 29-12-2012.
Time:3-Hrs.

Final-Term Exam of (Electrical Machines III)
For 4th Grad Electrical Engineering Dept. students.

Answer All Questions – Assume any missing data:

First Question: *(8 + 8 + 8 Marks)*

a) A 3-phase, 4-pole, 50 Hz, star-connected synchronous machine has an armature with diameter of 0.5 m and length of 0.3 m. The equation for flux density distribution is:

$$B = 0.15\sin\theta + 0.03\sin 3\theta + 0.02\sin 5\theta \ \text{wb/m}^2$$

Double layer winding is used for the armature which has 60 coils with 10 turns per coil, 60° phase spread, anda span of 13/15 of a pole pitch. ***Determine***the generated voltage between terminals.

b) ***Calculate*** the specific iron loss in a specimen of alloy steel for a maximum flux density of 3.2 Wb/m^2 and a frequency of 50 Hz, using 0.5 mm thick sheets. The resistivity of alloy steel is $0.3\times10^{-6}\ \Omega m$. The density is $7.8\times10^3\ Kg/m^2$. Hysteresis loss in each cycle is 400 J/m^3.

c) A turbo-alternator runs on test at a continuous rated load of 30 MVA with a lagging power factor of 0.8. The following cooling air measurements are taken:

Volume of cooling air measured at intake = 30 m^3/sec,
Intake air temperature = 15°C,
Outlet air temperature = 45°C,
Barometric reading = 750 mm of mercury.

(i) ***Find*** the efficiency of the machine, taking the specific heat of air at constant pressure as 1000J/Kg.°C, and the volume of 1 Kg of air is 0.78 m^3 at 0°C and a pressure of 760 mm mercury.

(ii) ***Estimate*** the amount of cooling water in liter/sec to cool the air, assuming the temperature rise of water to be 8°C.

Second Question: *(8 + 8 + 8 + 8 Marks)*

a) ***Discuss*** the cooling methods adopted for the following transformers:

i) Dry type. ii) Oil immersed type.

b) ***Explain*** the types of transformer tap changer, and***State*** the reasons of providing transformer tapping on the high voltage windings?

c) ***Explain*** and ***analyze*** the methods adopted for securing uniform surge voltage distribution over transformer windings?

d) ***Deduce*** the condition to design a transformer for minimum volume?

Third Question: *(15 + 15 Marks)*

a) ***Calculate*** the main dimensions and winding details of a 100 KVA, 2000/400 V, 50 Hz, single phase shell type, oil immersed, self-cooled transformer. Assume: voltage per turn 10 V, flux density in core and limb 1.1 Wb/m^2, current density 1.4 A/mm^2, window space factor 0.33. The ratio of window height to window width = 3; and ratio of core depth to width of central limb = 2.5. The stacking factor is 0.9.

b) A single phase, 400 V, 50 Hz, transformer is built from stampings having a relative permeability of 1000. The length of flux path is 2.5 m, the area of cross section of the core is 2.5×10^{-3} m^2 and the primary winding has 800 turns. ***Estimate*** the maximum flux and no-load current of the transformer. The iron loss at working flux density is 2.6 w/kg. specific iron weigh = 7.8×10^3 kg/m^3. Staking factor is 0.9.

Fourth Question: *(12 + 12 Marks)*

a) ***Prove*** that: The output equation of a "*m*" phase synchronous generator can be expressed as:

$$Q = C_o . D^2 . L . n_s$$

What is the main aim of applying this output equation?

b) The design details of two d.c. machines A and B are tabulated below. ***Compare*** their relative outputs.

Machine	Diameter, D [m]	Core length, L [m]	Speed n, [r.p.s]	Slots, S	Area of each slot, A_s [mm^2]	Slot space factor, S_f	B_{av} [Wb/m^2]	Current density, δ [A/ mm^2]
A	0.75	0.31	10	72	48×11	0.5	0.6	4.5
B	0.55	0.25	7.5	61	44×10	0.43	0.56	5.2

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2-3) For a compound d.c generator, ***deduce*** the conditions that the machine can be operate as: under, flat, and over cumulative compound generator.

2-4) **Compare** between metadyne transformer, metadyne generator, and amplidyne generator, then **Derive** the formula that describe the voltage amplification factor of metadyne/amplidyne generator.

Question № (3): (5 + 5 + 5 + 5 Marks)

3-1) For a cylindrical synchronous generator, ***deduce*** the relation between the reactive power and power angle, $Q = f(\delta)$, then ***explain*** the effect of the excitation on the generator operating point.

3-2) One important parameter of synchronous alternator is short-circuit ratio, ***explain*** how it can be estimated, then ***discuss*** its influence on the operating characteristics and the physical size of a synchronous alternator?

3-3) From the phasor diagram of a salient-pole synchronous motor working at a power factor lagging, ***derive*** the following relations:

$$\tan(\theta - \delta) = \frac{V_t \sin\theta - I_a X_q}{V_t \cos\theta - I_a r_a}; \quad \textit{and} \quad jE_f = V_t \cos\delta - I_a r_a \cos(\theta - \delta) - jI_d X_d$$

Where δ, θ are load and power factor angles respectively.

3-4) A 2-pole, 3-phase, star-connected, cylindrical synchronous machine has the following parameters:
Armature synchronous inductance, L_s = 0.01H/phase, negligible armature resistance.
Field self-inductance, L_f = 30 H, Field winding resistance, r_f = 20 Ω.
Maximum field to armature mutual inductance $M_{af\text{-}max}$= 0.5 H
The machine is working as a generator at rated speed, delivers power to a balanced load at unity P.F. Field windings is energized from 200 V dc source. If the voltage across the load terminals is 900 V/phase, ***compute*** the electrical output power.

Question № (4): (10 + 10 + 10 Marks)

4-1) From the primitive equivalent model of a three-phase induction machine, ***prove*** that the electromagnetic develop torque, T_e is given by:

$$T_e = \text{Re}\left(j2M\, I_2^* I_1\right)$$

Where, I_1 : is stator current, I_2 : is rotor current, and M : is stator to rotor mutual inductance.

4-2) ***Explain*** the performance of the induction motor under the following operating cases:
i) Variable voltage, constant frequency,
ii) Constant voltage, variable frequency, and
iii) Variable voltage, variable frequency.

4-3) A three-phase cage induction motor operates at its rated voltage and frequency and has a rotor copper loss at maximum torque equals to 9 times that at full-load torque and has a slip of 3 % at full-load. Neglecting stator resistance and rotational losses, ***calculate***:
i) The maximum torque and its corresponding slip, and
ii) The starting torque. Express the torques in terms of full-load torque.

Good Luck *Dr, Mohamed Eid*