Birla Institute of Technology and Science, Pilani

Semester-I, 2013-14

Comprehensive Examination (Close Book)

Course No. : EEE C371 (Electro Mechanical Energy Conversion)

Date: 11-12-2013 **Max. Time - 180 Min.** **Marks -120**

Name	ID. No.

Instructions: Question Paper is in 2-Parts **A & B**. Part **A**, has to be answered in Question paper itself.

PART – A

Marks – 4x10 = 40 **Max. Time - 60 Min.**

Q.1. A 50 hp, 3-phase, star connected Induction motor operates at an efficiency of 85% and 0.8 lagging power factor when connected to 3-phase, 500V mains. The per phase current and reactive power drawn by the motor is ________________ and _________________ respectively.

Q.2. A 200/100 V, 50 Hz, single phase transformer has primary leakage impedance 0.15+ j 0.76 Ω and secondary leakage impedance 0.04+ j0.19 Ω. The transformer supplies a load of impedance 3.92+ j 2.62 Ω. The voltage regulation and efficiency of the transformer, if the primary is supplied at rated voltage are ________________ and _________________ respectively.

Q.3. Two single-phase transformers operate in parallel to supply a load of 44+j18.6 Ω. The transformer-A has a secondary emf. of 400 V on open circuit with an internal impedance of 1.8+j5.6 Ω referred to the secondary. The corresponding figures for transformer-B are 410 V and 1.8+j7.4 Ω. The current supplied by each transformer is_____________ and ________________ respectively.

Q.4. A 20 hp, 60 Hz, three phase induction motor has a rated speed of 1723 rpm. If the friction and windage losses amount to 5% of the output power. The rotor copper losses and air gap power is_____________ and ________________ respectively.

Q.5. The supply connected to the stator of a three phase induction motor feeds 29kW at 50 Hz, of which 25kW is transferred to the rotor, the rotor copper loss amounts to 2.9kW, and 21kW is obtained as output power. The stator iron loss for this machine can be assumed to remain constant at 1.3kW. The frequency of the rotor circuit and motor slip is____________ and ____________ respectively.

Q.6. A 200V, 7.5 kW, separately excited dc motor has an armature resistance of 0.25 Ω and a field resistance of 200 Ω. The machine runs at 1800 rpm to supply full load at 90 % efficiency. The no load current and speed is ____________ and _________________ respectively.

Q.7. A 115 V, 4-pole, 60 Hz, single phase Induction Motor is rotating clockwise at a speed of 1710 rpm. Its perunit slip in forward and back word direction is__________and____________ respectively.

Q.8. A 6.6 kV, 50Hz star connected 3 phase synchronous generator, having a per-phase synchronous reactance of 9.5 Ω, operates on 6.6kV infinite bus bars with the field current set to produce excitation emf. of 1.1 pu. The maximum power that this generator can feed to the bus bars, and the power factor at which it will do so are _______________ and ______________ respectively.

Q.9. A 3-phase, star connected alternator rated for 230V operation, the per phase resistance and synchronous reactance are 0.15 Ω and 9 Ω, respectively. The excitation emf, and load angle for the alternator when alternator is delivering 9 A at UPF are_________ and ____________ respectively.

Q.10. A 3-phase star connected alternator has 81 slots, 6-poles, and a double layer winding having a coil span of 13 slots. The breadth and pitch factor for the fundamental component of voltage are _____________ and ______________ respectively.

.

Max. Time - 120 Min. **PART – B** **Marks – 80**

Instruction: Attempt all the parts of a question in sequence.
Solution must be neat and clean, showing all major steps for full credit.

Q.1. a. Show that kVA rating of an Auto-transformer is grater than a two winding transformer when it is configured as an Auto-transformer. Also discuss the advantages & disadvantages of an Auto-transformer.

Q.1.b. For a 6600/384V, 200kVA, single phase transformer, the efficiency at half and full load is 98% when operating at upf. The no load pf is 0.2 lagging, and the full load voltage regulation at 0.8 lagging pf is 4%. Draw the approximate equivalent circuit referred to low voltage side and insert all the impedance value.

[10+10]

Q.2. a. Show that in a 3-phase Induction Motor, torque at any slip is (assume stator impedance is zero)

$$\mathbf{T = 2\,T_{Max} \Big/ (S/\,S_{Max} + S_{Max}/\,S)}$$

Q.2.b. Explain with the help of two field reaction theory that the starting torque of Single phase Induction Motor is zero.

The 3-phase squirrel cage Induction Motor, with negligible core and mechanical losses and magnetizing current under all operating conditions is fed from a variable voltage & variable frequency source. If the motor is always made to operate at the same slip, how does the efficiency vary with operating condition? Justify with the relevance derivation only**.**

[10+15]

Q.3.a. A 2.3kV, 3-phase synchronous motor, driving a pump, is provided with an arrangement to vary the field excitation. Neglecting the losses, what is the power delivered to the pump when the excitation is set corresponding to a minimum AC line current of 8.8 A? What will be the current drawn and reactive power supplied by the motor system, if the excitation is set so as to make the motor power factor 0.8 leading.

Q.3.b. Explain significance of term SCR (Short Circuit Ratio).

A 2 MVA, 50 Hz, 3-phase, 3.3 kV star connected synchronous generator has a per phase synchronous impedance of j5.5 Ω. Under normal operating conditions, the generator delivers 1.5MW at lagging power factor of 0.8 to infinite bus bars at rated voltage. Keeping the excitation constant, find the current and power factor at the stability limit for the machine.

Q.3.c. A 240 V DC series motor has an armature + field resistance of 0.2Ω. When operating at 1800 rpm, the motor takes a current of 40A. Find the external resistance to be added in series so as to limit the current at 10 A when operating at 3600 rpm. Assume the mechanical losses to be negligible, the filed flux to be proportionate to current when operating in the 10-40 A range.

[10+15+10]

GOOD LUCK

Mid- Sem Test Solution- EEE C371_2013

Sol.1- Given Transf. 16.67 kVA , 7200/120V; approximate equivalent ckt. referred to HV side.

X_{eq}= X_1 + 60^2 X_2 ; (where X_1 & X_2 are the leakage reactances of primary & secondary side)

Taking load side terminal voltage as reference.

V_L' =7200∟0^o ; since load is resistive

I_2 = (16.67x1000)/120 = 139∟0^o amp. -LV side

I_2' = 139/60 = 2.32 ∟o^0 Amp.—HV side ---------(2)

E = V_2' + I_2' (R_{eq}+jX_{eq}); = 7200∟0^o + 2.32∟0^0 (37.38+j155.56)

E= 7286.56 + j360.13 V; E=V_1= 7296∟3^o V---------(2)

Primary Current I_1= I_o +I_2'

I_o=I_i +I_m ; Core loss component Current I_i =(V_1/R_C) = 7295/(311x10^3) = ***0.0234∟3^0 Amp.*** ---------(2)

I_m= V_1/(jX_m) = 7296∟3^o/(58x10^3 ∟90^0) = 0 .1257∟-87^o

I_1=I_o+I_2' = 2.32∟0^0 +0 .127∟-77^o = ***2.34 ∟-3^o Amp.***

Copper Loss = $I_2'^2$x Req = 2.32^2 x37.38 = ***201 Watt***

Core Loss = ($V_1^{\ 2}$/R_C)

= $(7295)^2$/(311x10^3) = ***170 Watt***------(2)

Efficiency (η) = Out Put Power/Input Put Power

= (16.67x10^3 x1)/((16.67x10^3)+201+170)

= (16670/17045)x100% = ***97.82%***- ------(2)

Sol. 1(b) :

25 kVA, 660/220 V, Auto. Transformer.

P_{cu}(full L load) = 320 Watt ; P_i = 360 Watt

Efficiency (η) = Out Put Power/Input Put Power = (0.9x25x10^3 /(0.9x25x10^3)+680) = 97%---------(2)

For % vol. regulation. The step up Auto transformer is assumed to be made out of 440/220 V; 16.67 KVA two winding transformer.

25x10^3 =V_1 X I_1 = 660xI_1 ; i.e I_1 = 37.82 Amp

220xI_2 = 25x10^3; So I_2 = 113.63 Amp.

VA rating of two winding transf. is

V_2 x(I_2–I_1)= 16.67 kVA------(2)

$I_2^{\ 2}$ xR_{eq} = 320

→ Req = 320/37.86^2 = 0.223 Ω---------(2)

Zeq = 27.6/37.86 = 0.73 Ω. Xeq =√ (Z_{eq}^2- R_{eq}^2) = 0.48 Ω

%V.R = (I_{rated} x(Req cosϕ + Xeqsinϕ))/V_{rated}.

= (37.86x(0.223x0.9)+(0.48x0.435))/440 = **3.5%----(2)**

Sol 2(b):

Given $Z_L = 44+j18.6\ \Omega$,

$E_A = 400$ V, $Z_A = 1.8+j5.6\ \Omega$,

$E_B = 410$ V, $Z_B = 1.8+j7.4\ \Omega$;

Current through the transf.

$I_A = ((E_A Z_B)+(E_A-E_B)Z_L)/((Z_A Z_B)+(Z_A+Z_B)Z_L)$ &

$I_B = ((E_B Z_A)-(E_A - E_B)Z_L)/((Z_A Z_B)+(Z_A + Z_B)Z_L)$

Circulating current I_C(current flow through the windings when load is not connected) .

$I_C = (E_A \sim E_B)/(Z_A + Z_B)$

$I_C = 10/(3.6+j13) = 10/(13.5\llcorner -74.5^o)$ amp--------**(2)**

Putting the values and simplifying then.

$I_A = 4.1\llcorner -16^o$, ---------**(2)** $I_B = 4.08\llcorner -36^o$, ---------**(2)**

$V_L = E_A - (I_A Z_A) = 400\llcorner 0^o - (4.10\llcorner -16^o \times (18+j5.6))$

$= 387\llcorner -3^o$ V---------**(2)**

$PF_a = \cos(12^o) = 0.96$ lag.; $PF_b = \cos(33^o) = 0.8$ lag---------**(2)**

Sol. 3(a) :

The 3 single phase transf. of 11kV/230V ; 110kVA

$Z_{base(LV)} = 230^2/(110\times10^3) = 0.48\ \Omega$

$Z_a = 0.1$ pu, $Z_b = 0.12$pu, $Z_c = 0.15$pu

$Y_{net} = Y_A + Y_B + Y_c = (1/0.1) + (1/0.12) + (1/0.15) = 25$pu. --------**(2)**

From current division method

$I_A = I_L x (Y_A / Y_{net}) = 0.4 I_L$

$I_L = 1200\llcorner -26^o = 2.5\llcorner -26^0$, --------**(2)**

$I_{Base} = (110\times10^3)/230 = 478$ Amp

$\rightarrow I_A = 2.5\times0.4\llcorner -26^o$ pu $= 1\llcorner -26^0$ pu = 480 Amp. ------**(2)**

Similarly $I_B = (Y_B/Y_{net}) x I_L = 400\llcorner -26^0$ Amp.

$I_C = (Y_C/Y_{net}) \times I_L = 320\llcorner -26^0$ Amp;

terminal voltage $V_L = |V|\llcorner 0^o = E_A - I_A Z_A$

$= 1\llcorner 0^0 - (1\llcorner -26^o \times 0.1\llcorner -90^o) = (\cos\phi + j\sin\phi) - 0.1(\cos64^o + j\sin64^o) \rightarrow \phi = 5^o$,

$E = 230\llcorner 5^0$ V, --------**(2)** ; $V_t = 220\llcorner 0^o$ V

Load shared by each transformer.

$S_A = V_L.I_A = 105$ kVA. $S_B = 87.52$ KVA, $S_C = 63.0$ kVA --------(2)

Sol. 3(b):

Since 2-phase load is 50 kVA at 0.8pf; each phase load current

$25\times10^3 = 220\times |I_a = I_b| \rightarrow |I_a| = 113.63$amp $= |I_b|$

$V_b = 220\llcorner 0^o$; $V_a = 220\llcorner 90^o$; $I_b = 11.63\llcorner -37^o$;

$I_a = 113.63\llcorner 53^o$ Amp. --------**(2)**

Line Currents are

$I_B = I_{BC} - I_{A/2}$; $I_C = -(I_{BC} + I_{A/2})$

$(3^{1/2}/2)N_1 I_A = N_2 I_a$

$\rightarrow I_A = (2/3^{1/2})(N_2/N_1) I_a$

$= (113.63\llcorner 53^o)/3$ = **$65.6\llcorner 53^o$ Amp.** ----**(2)**

$I_A = 65.6\llcorner 53^o$ Amp.

$I_{BC} = (N_2/N_1) x I_b = I_b /2$;

$= (113.63\llcorner -37^o)/2 = 56.8\llcorner -37^o$ amp--------**(2)**

$I_B = I_{BC} - I_{A/2} = (56.8\llcorner -37^0) - (65.6\llcorner 53^o) = (45.36-j34.18)-(19.74+j26.2) = (25.62-j60.5)$=**$65.63\llcorner -67^o$ Amp**

$I_B = 65.63\llcorner -67^o$ Amp.

$I_C = -65.68\llcorner -70 = 65.68\llcorner 173^o$ Amp. --------(2)