REF:EX/PE/T/326/2018

Bachelor of Power Engineering 3rd year 2nd Semester Examination 2018

Sub: Electrical Machine and Power Control

Full Marks: 100 **Time: 3 Hours**

Q1. Define**any four** of the following: (2×4 = 08)

(a) Closed loop speed control of induction-motor drive
(b) Regenerative braking of induction motors
(c) Classes of motor duty
(d) Bus Incidence Matrix
(e) Automatic Generation Control
(f) Swing Equation
(g) Different cost coefficients of a thermal generating unit

Q2. Answer **any four** of the following: (5×4=20)

a) Derive the expression of swing equation in the following form: $(H/\Pi f)(d^2\delta/dt^2) = P_m - P_e$. All the symbols have their usual meaning.

b) Derive for equal area criterion: $d\delta/dt = (2/M\int_{\delta 0}^{\delta} P_a\, d\delta)^{1/2}$. All the symbols have their usual meaning.

c) For optimal generation scheduling considering transmission loss, show that

$$[(dC_i/dP_{Gi})/(1-\delta P_L/\delta P_{Gi})] = \Lambda.$$

All the symbols have their usual meaning.

d) Deduce the expression for reactive power in terms of V_i, V_k, Y, Θ_k for Load Flow Studies

e) From the load-frequency characteristics, find Δf in terms of B, R, ΔP_C. All the symbols have their usual meaning.

f) Derive the expression for induction motor torque in terms of supply voltage from the equivalent circuit. Assume the parameters and mention them precisely.

g) Derive the expression $V_a = 2V_m/\Pi\ \cos\alpha$ for continuous conduction in case of single phase fully controlled rectifier control of DC separately excited motor. All the symbols have their usual meaning.

Q3. Answer **any SIX** of the following: (6×12=72)

(a) A 415V, 4 pole, 50Hz, 1440rpm, delta connected squirrel-cage induction motor has the following parameters:

$$R_S = 0.3\Omega,\ R_R' = 0.45\Omega,\ X_S = 0.7\Omega,\ X_R' = 0.9\Omega$$

The motor is fed from a voltage source inverter with a constant V/f ratio from 0 to 50Hz and at the rated voltage above 50Hz frequency.

(i) Determine the breakdown torque for a frequency of 75Hz for both motoring and braking operations.
(ii) Frequency of motoring operation at 1000rpm and full-load torque.
(iii)Calculate the full-load torque for regenerative braking at 30Hz.

(b) A 3-phase, 415V, 50Hz, 6 pole, 1000 rpm, Y-connected wound rotor induction motor has the following constants referred to the stator:

$$R_S = 0.5\Omega,\ R_R' = 0.75\Omega,\ X_S = 1.2\Omega,\ X_R' = 1.5\Omega$$

The speed of the motor is reduced to 800rpm at half full load torque by injecting a voltage in phase with the source voltage into the rotor. Stator to rotor turns ratio is 2.4.

(i) Calculate the magnitude and the frequency of the injected voltage

(c) A 230V, 960 rpm and 200A separately excited dc motor has an armature resistance of 0.02Ω. The motor is fed from a chopper which provides both motoring and braking operations. The source has a voltage of 230V. Assuming continuous conduction.

(i) Calculate the duty ratio of chopper for motoring operation at rated torque and 750 rpm.

(ii) Calculate the duty ratio of chopper for motor speed of 600 rpm and braking torque of twice the rated value.

(d) A 220V, 900rpm, 175A separately excited dc motor has an armature resistance of 0.06Ω. It is fed from a single phase fully controlled rectifier with an ac source voltage of 220V, 50Hz. If the armature circuit inductance of motor of the drive be 0.85mH, calculate the motor torque for

(i) $\alpha = 60^0$ and speed = 400 rpm.

Now external inductance of 2mH is added to the armature circuit to reduce the region of discontinuous conduction. Calculate the torque for

(ii) $\alpha = 120^0$ and speed = 400 rpm.

(e) A 50Hz synchronous generator with inertia constant H=4.0s and a transient reactance of 0.15pu feeds 0.85p.u active power into an infinite bus (voltage 1 pu) at 0.85 lagging pf via a network of equivalent reactance of 0.25pu. A Three phase fault is sustained for 150 ms across generator terminals. Determine through swing curve calculation the torque angle, 250 ms after fault initiation.

(f) A synchronous generator represented by a voltage of 1.10 pu in series with a transient reactance is connected to a large power system with voltage 1.0 pu through a power network. The equivalent transient transfer reactance X between voltage sources is j0.40 pu(imaginary).

After the occurrence of a three-phase to ground fault on one of the lines of the power network, two of the line circuit breakers A and B operate sequentially as follows with corresponding transient transfer reactance given therein.

(i) Short circuit occurs at $\delta = 30^\circ$, A opens instantaneously to make $X = 3.0$ pu.

(ii) At $\delta = 60^\circ$, A recloses, $X = 6.0$ pu.

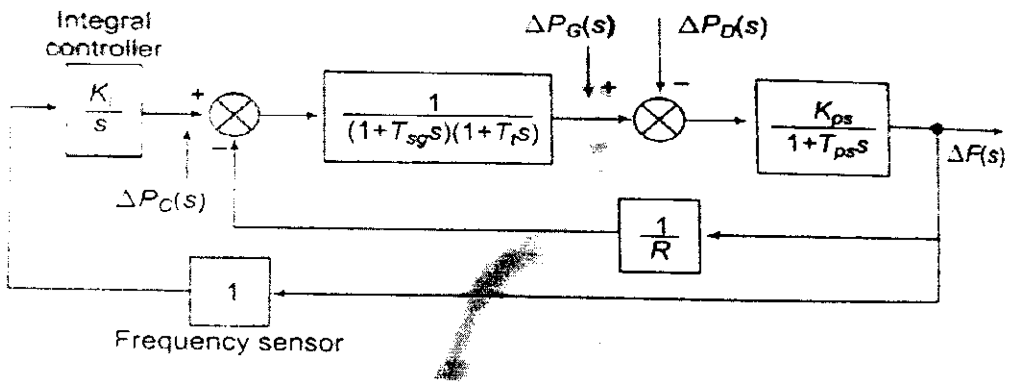
(iii) At $\delta = 75^\circ$, A reopens

(iv) At $\delta = 90^\circ$, B also opens to clear the fault making $X = 0.60$ pu

Check if the system will operate stably.

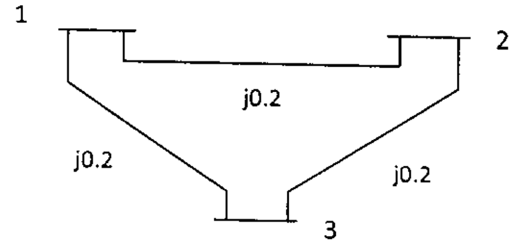
(g) Two generators rated 200 MW and 500 MW are operating in parallel. The droop characteristics of their governors are 3.5% and 5 % respectively from no load to full load. Assuming that the generators are operating at 50Hz at no load, how a load of 550MW is shared between them? What will be the system frequency at this load? Assume free governor operation.

(h) For the load frequency control with proportional plus integral controller as shown below, obtain an expression for the steady state error in cycles, i.e. $\int_0^t \Delta f(t)dt$; for a unit step ΔP_D. What is the corresponding time error in seconds (w.r.t 50Hz)? Comment on the dependence of error in cycles upon the integral controller gain K_i.



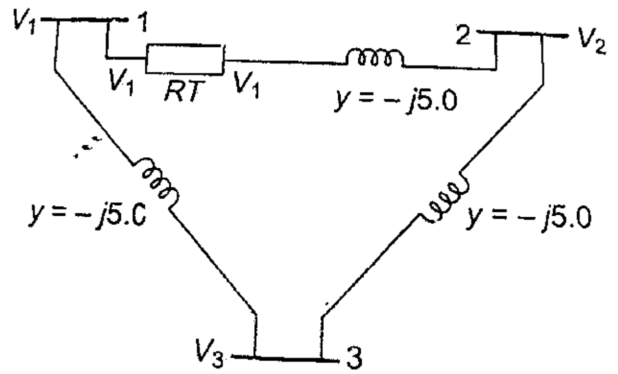
(i) Consider a three-bus system as shown below. Considering $|V_1| = 1.0, |V_2| = 1.05, |V_3| = 0.8$, carry out the approximate load flow solution.

Bus	Real Demand	Reactive Demand	Real Generation	Reactive Generation
1	$P_{D1} = 1.0$	$Q_{D1} = 0.6$	$P_{G1} = ?$	Q_{G1} (unspecified)
2	$P_{D2} = 0$	$Q_{D2} = 0$	$P_{G2} = 1.5$	Q_{G2}(unspecified)
3	$P_{D3} = 0.95$	$Q_{D3} = 1.0$	$P_{G3} = 0$	Q_{G3}(unspecified)



(j) Find out the modified Y-BUS matrix for the following three-bus system and solve the load flow equation for: RT magnitude regulator with ratio $= \frac{V_1}{V_1'} = 0.99$

Bus	Real Demand	Reactive Demand	Real Generation	Reactive Generation
1	$P_{D1} = 1.0$	$Q_{D1} = 0.6$	$P_{G1} = ?$	Q_{G1} (unspecified)
2	$P_{D2} = 0$	$Q_{D2} = 0$	$P_{G2} = 1.5$	Q_{G2}(unspecified)
3	$P_{D3} = 0.95$	$Q_{D3} = 1.0$	$P_{G3} = 0$	Q_{G3}(unspecified)



(k) The incremental fuel costs for two units of a plant are :

$$\lambda_1 = df_1/dP_{g1} = 0.012P_{g1} + 8.0$$
$$\lambda_2 = df_2/dP_{g2} = 0.008P_{g2} + 9.6$$

where, f is in \$/h and P_g is in MW. If both units operate at all times and maximum and minimum loads on each unit are 550 and 100 MW, respectively, plot λ of the plant in \$/MWh versus plant output in MW for economic dispatch as total load varies from 200 to 1100 MW.