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ESE 2022 : Prelims Exam
CLASSROOM TEST SERIES

ELECTRICAL ENGINEERING

Test 8

Section A : Power Systems [All Topics]

Section B : Electrical Machines-1 [Part Syllabus]

Section C : Control Systems-2 [Part Syllabus] + Engineering Mathematics-2 [Part Syllabus]

1.	(c)	**16.**	(a)	**31.**	(b)	**46.**	(a)	**61.**	(a)
2.	(d)	**17.**	(d)	**32.**	(c)	**47.**	(a)	**62.**	(a)
3.	(a)	**18.**	(c)	**33.**	(b)	**48.**	(c)	**63.**	(b)
4.	(a)	**19.**	(d)	**34.**	(d)	**49.**	(b)	**64.**	(a)
5.	(a)	**20.**	(a)	**35.**	(c)	**50.**	(b)	**65.**	(c)
6.	(b)	**21.**	(d)	**36.**	(a)	**51.**	(c)	**66.**	(a)
7.	(d)	**22.**	(b)	**37.**	(d)	**52.**	(a)	**67.**	(c)
8.	(b)	**23.**	(c)	**38.**	(b)	**53.**	(d)	**68.**	(d)
9.	(b)	**24.**	(c)	**39.**	(b)	**54.**	(a)	**69.**	(a)
10.	(b)	**25.**	(c)	**40.**	(b)	**55.**	(d)	**70.**	(c)
11.	(c)	**26.**	(d)	**41.**	(d)	**56.**	(d)	**71.**	(c)
12.	(a)	**27.**	(c)	**42.**	(c)	**57.**	(c)	**72.**	(c)
13.	(d)	**28.**	(a)	**43.**	(c)	**58.**	(b)	**73.**	(c)
14.	(a)	**29.**	(a)	**44.**	(c)	**59.**	(a)	**74.**	(b)
15.	(b)	**30.**	(b)	**45.**	(a)	**60.**	(d)	**75.**	(a)

DETAILED EXPLANATIONS
Section A : Power Systems

1. (c)

Let load resistance is R, so total power

$$P_{L1} = \frac{3V^2}{R} \qquad \text{...(i)}$$

If one resistor is replaced with $2R$ resistance

So total load power,

$$P_{L2} = \frac{2V^2}{R} + \frac{V^2}{(2R)} = 2.5\frac{V^2}{R} \qquad \text{...(ii)}$$

$$\text{\% reduction in load} = \frac{P_{L1} - P_{L2}}{P_{L1}} \times 100 = \frac{\frac{3V^2}{R} - \frac{2.5V^2}{R}}{\frac{3V^2}{R}} \times 100$$

$$\text{\% reduction} = 16.67\%$$

2. (d)

1 and 3 are correct statements.

- Because of bad atmospheric conditions, the disruptive voltage reduces, so Corona loss increases.
- Corona loss $P_L \propto (V_p - V_0)^2$ loss will be present if only $V_P > V_0$.

  $V_0 \rightarrow$ disruptive voltage

  $V_p \rightarrow$ operating voltage

- In hilly area, the value of $\delta = \frac{3.92b}{273 + t}$ is lower compared to plain area. Because of δ, the value of disruptive voltage is discreased and Corona loss is proportional to

$$P_L \propto \frac{1}{\delta}(V_p - V_0)^2$$

  here $\delta \downarrow$, and $V_0 \downarrow$, so $P_L \uparrow$

So statement 1 and 3 are correct.

3. (a)

Using the theorem of complex power, the complex power into inductor is

$$S_1 + S_2 = VI^* = j\omega L|I|^2$$

Thus, $\quad P_1 + P_2 = 0$

and $\quad Q_1 + Q_2 = \omega L|I|^2$

Now using, $\quad |V_2| = |V_1|$,

We find $S_1 = V_1 I^*$

$S_2 = -V_2 I^*$

$\Rightarrow \quad |S_1| = |S_2|$

$\Rightarrow \quad P_1^2 + Q_1^2 = P_2^2 + Q_2^2$

But since, $|P_1| = |P_2|$

We get $|Q_2| = |Q_1|$

As a result, $Q_1 = Q_2 = \frac{1}{2}\omega L|I|^2$

and finally $P_2 = -P_1$

$Q_2 = Q_1$

$\Rightarrow \quad S_2 = -S_1^*$

4. (a)

$$\text{GMR} = (r' d_{12} d_{13})^{1/3}$$

$$\text{GMR} = (0.7788 \times 2 \times 50 \times 50)^{1/3}$$

$$= (1.56 \times 50 \times 50)^{1/3} = (3900)^{1/3}$$

$$\text{GMR} = 15.70 \text{ cm}$$

5. (a)

$$P_e = 2 \sin \delta$$

$$S = \frac{dP_e}{d\delta} = 2\cos\delta$$

So, $$\frac{S_1}{S_2} = \frac{\cos\delta_1}{\cos\delta_2} \Rightarrow \frac{S_1}{S_2} = \frac{\cos 30°}{\cos 45°}$$

$$\frac{S_1}{S_2} = \frac{\sqrt{3}}{2} \times \sqrt{2} = \sqrt{\frac{3}{2}}$$

6. (b)

Water carrying pipe from the surge tank to turbine blades or dam to surge tank is called penstock. A penstock is used as a conduit between dam (reservoir) and turbine in a hydrostation.

7. (d)

With V_{ab} as reference

$V_{ab} = 173.2\angle 0°$ V, $\quad V_{an} = 100\angle -30°$ V

$V_{bc} = 173.2\angle -120°$ V, $\quad V_{bn} = 100\angle -150°$ V

$V_{ca} = 173.2\angle 120°$ V, $\quad V_{cn} = 100\angle 90°$ V

$$\vec{I}_C = \frac{V_{cn}}{Z_L} = \frac{100\angle 90°}{10\angle 20°} = 10\angle 70° \text{ A}$$

8. (b)

$$\text{Power} = \frac{1}{2} C_p \rho A V^3$$

$C_p = 0.4$

= Power coefficient gives the maximum amount of wind power that can be converted into mechanical power by wind turbine

$A = \pi r^2 = 3.14 \times 3^2 = 28.26 \text{ m}^2$

$V = 5 \text{ m/s}, \quad \rho = 1.24 \text{ kg/m}^3$

$$\text{Power} = \frac{1}{2} \times 0.4 \times 1.24 \times 28.26 \times 5^3 \times 10^{-3}$$

$= 0.88$ kW

9. (b)

The distribution of current throughout the cross-section of conductor is uniform only when DC is passing through it on the contrary when AC is flowing through a conductor, the current is non-uniformly distributed over the cross-section in a manner that current density is higher at surface of conductor compared to the current density at its centre.

This effect becomes more pronounced as frequency is increased. This phenomenon is called skin effect. Since flux in directly related with current, so because of high frequency, flux inside conductor will decrease.

10. (b)

The real power, $P_r = \frac{|V_1||V_2|}{X} \sin\delta$

$$\frac{1}{\sqrt{2}} = \frac{1 \times 1}{1} \sin\delta$$

$\delta = 45°$

The sending end reactive power,

$$Q_S = \frac{V_s^2}{X} - \frac{V_S V_R}{X}\cos\delta = \frac{1^2}{1} - \frac{1 \times 1}{1}\cos 45°$$

$$= 1 - \frac{1}{\sqrt{2}} = \frac{\sqrt{2}-1}{\sqrt{2}} = 0.293 \text{ p.u.}$$

11. (c)

For generator-1, $\Delta f = \frac{4}{100} \times 50 = 2$ Hz for $P_1 = 200$ MW

For generator-2, $\Delta f = \frac{5}{100} \times 50 = 2.5$ Hz for $P_2 = 400$ MW

If operating frequency, $f = 48.5$ Hz

The change in frequency,

$$\Delta f_L = 50 - 48.5 = 1.5 \text{ Hz}$$

Now power shared by generator-1,

$$= P_1 = \frac{200}{2} \times 1.5 = 150 \text{ MW}$$

and power shared by generator-2

$$P_2 = \frac{400}{2.5} \times 1.5 = 240 \text{ MW}$$

So total load will be, $P_L = P_1 + P_2 = 150 + 240$

$$P_L = 390 \text{ MW}$$

12. (a)

Statement 1 and 2 are correct. Statement 3 is not correct.

The surge impedance of Z_S ohm means line can be theoretically loaded upto Z_S ohm.

13. (d)

All statements are correct.

Statement-1 : If frequency in increasing, the value of capacitance reactance is going to decrease, so charging MVAR increase.

$$P_C \propto \frac{V^2}{X_C} \propto V^2(2\pi f C)$$

$$Q_C \propto f$$

If $f \uparrow$, $Q_C \uparrow$.

14. (a)

The capacity of the pumped storage power plant comparising of pondage should be such that plant can supply peak load for 4 to 10 hours.

15. (b)

We know,

Coordination equation,

$$\frac{dC_n}{dP_{Gn}} \cdot L_n = \lambda$$

or

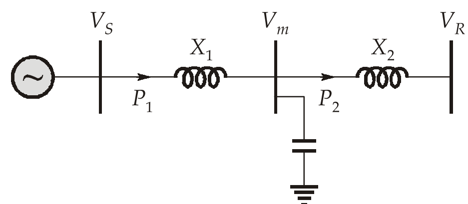
$$\frac{dC_n}{dP_{Gn}} \left[\frac{1}{1 - \frac{\partial P_L}{\partial P_{Gn}}} \right] = \lambda$$

Where, L_n is penalty factor

$$L_n = \frac{1}{1 - \frac{\partial P_L}{\partial P_{Gn}}}$$

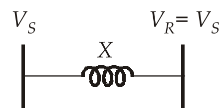
16. (a)

In mid point compensation power flow depends up on minimum power flows in two sections.

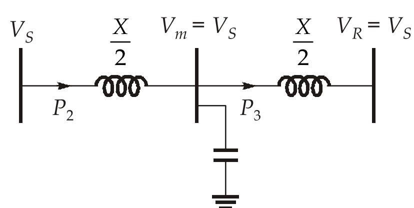


$$P_1 = \frac{V_S V_m}{X_1}; \qquad P_2 = \frac{V_m V_R}{X_2}$$

Minimum of P_1(or) P_2 flows through the transmission line.

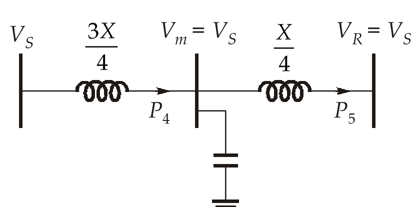


$$P_1 = \frac{V_S^2}{X}$$



$$P_2 = \frac{V_S V_m}{\frac{X}{2}} = P_3$$

$$P_2 = P_3 = \frac{2V_S^2}{X}$$



$$P_4 = \frac{V_S^2}{\frac{3X}{4}} = \frac{4V_S^2}{3X}$$

$$P_5 = \frac{V_S^2}{\frac{X}{4}} = \frac{4V_S^2}{X}$$

In P_4 and P_5, P_4 is less

The ratio's of maximum powers are,

$1 : 2 : \frac{1}{0.75}$

17. (d)

Given,

Maximum demand, MD = 40 MW

Capacity factor = 0.5

Utilization factor = 0.8

Load factor,

$$\frac{\text{Capacity factor}}{\text{Utilization factor}} = \frac{0.5}{0.8} = 0.625$$

$$\text{Plant capacity} = \frac{\text{Maximum demand}}{\text{Utilization factor}} = \frac{40}{0.8} = 50 \text{ MW}$$

$$\text{Reserve capacity of plant} = \text{Plant capacity} - \text{Maximum demand}$$

$$= 50 - 40 = 10 \text{ MW}$$

18. (c)

Number of units, $n = 3$

Ratio of shunt capacitance to mutual capacitance,

$$K = \frac{0.1x}{x} = 0.1$$

Voltage across bottom most unit = 20 kV

Voltage across top most unit,

$$V_1 = \frac{20}{1+3\times 0.1+(0.1)^2} = \frac{20}{1+0.3+0.01} = 15.267 \text{ kV}$$

$$\text{Voltage across middle unit} = (1 + K)V_1$$

$$= 15.267 \times (1.1) = 16.794 \text{ V}$$

Maximum safe operating voltage of string = 15.267 + 16.794 + 20 = 52 kV

19. (d)

- Current limiting reactor help to reduce the flow of current in short-circuit to protect the apparatus from mechanical stress, overheating due to faults and thereby protects the whole system.
- The short-circuit causes disturbance in the voltage and the current limiting reactor helps to minimize the magnitude of the disturbance voltage.
- The current limiting reactors helps in localizing the faults by limiting the current flowing into the faulty section from other healthy sections of the system. This will avoid the fault from spreading in the system and thereby increases the chance of continuity of supply.

All given statements are correct.

20. (a)

We know,

Characteristic impedance, $Z_C = \sqrt{\frac{L}{C}}$

For 36% series compensation,

$$Z_{C2} = \sqrt{0.64}\, Z_{C1}$$

[∵ Series compensation, compesates the effect of inductive reactance in the line]

So surge impedance loading,

$$\text{SIL}_2 = \frac{SIL_1}{\sqrt{0.64}} = \frac{SIL_1}{0.8}$$

∴ % increment in surge impedance loading

$$= \frac{SIL_2 - SIL_1}{SIL_1} = \frac{\left(\frac{SIL_1}{0.8} - SIL_1\right)\times 100}{SIL_1} = \frac{1-0.8}{0.8}\times 100$$

$$= \frac{0.2}{0.8}\times 100 = 25\%$$

21. (d)

Order of Jacobian matrix = $(2n - m - 2) \times (2n - m - 2)$

Where 'n' is number of buses

m is the number of PV buses

∴ Order of Jacobian = 2 × 194 – 43 – 2

= 388 – 45 = 343

Matrix order = 343 × 343

22. (b)

We know, prospective instantaneous voltage,

$$V = i\sqrt{\frac{L}{C}} = 12\sqrt{\frac{1}{0.04\times 10^{-6}}} = \frac{12}{0.2\times 10^{-3}} = 60 \text{ kV}$$

23. (c)

If all the sequence voltages at the fault point in power system are equal, then occurred fault is LLG fault.

24. (c)

Operating current of relay = Pickup current

I_{pickup} = Relay setting × rated current of relay

= 1.20 × 8

= 9.6 A

25. (c)

Total reactance, $X = 1.2 + 0.4 + 1.4 = 3$ p.u.

$E_1 = 2.4$ p.u.

and $E_2 = 1.6$ p.u.

$$P = \frac{E_1 E_2}{X}\sin\delta$$

$$\sin\delta = \frac{PX}{E_1 E_2} = \frac{0.5\times 3}{2.4\times 1.6} = \frac{1.5}{3.84} = 0.3906$$

$$\delta = \sin^{-1} 0.3906 \approx 23^\circ$$

26. (d)

$$\Delta V_R = \frac{4\pi^2 f^2 l^2 V_s}{v^2}$$

$$= \frac{4\pi^2\times 50^2\times(200\times 10^3)^2\times 1}{(3\times 10^8)^2} = 0.043 \text{ p.u.}$$

$$V_R = V_S + \Delta V_R$$

$$= 1 + 0.043 = 1.043 \text{ p.u.}$$

27. (c)

Ratio of maximum dielectric stress to minimum dielectric stress is $\frac{R}{r}$.

28. (a)

For accurate load flow calculations on large power system, the best method is Newton Raphson method.

29. (a)

To neutralize the capacitive charging current or earth fault, the value of the inductance reactance of the Peterson coil,

$$X_L = \frac{1}{3\omega C}$$

If 95% the total capacitive reactance is to be neutralized,

then $$X_L = \frac{1}{0.95\times 3\times 100\pi\times 2\times 10^{-6}}$$

$$= 559\ \Omega$$

30. (b)

PSM (Plug Setting Multiplier) is ratio between the actual fault current in the relay operating coil to pick up current or the relay current setting,

$$\text{PSM} = \frac{I_F}{\text{current setting} \times \text{CT ratio}}$$

$$8 = \frac{I_F}{1.20 \times \frac{500}{1} \times 1}$$

$$I_F = 4800 \text{ A}$$

31. (b)

The power loss can be written as

$$P_L = B_{11}P_{G1}^2 + B_{22}P_{G2}^2 + 2B_{12} \cdot P_{G1}P_{G2}$$

$$= 0.002\ (100)^2 + (0.0015) \times (50)^2 - 2 \times 0.0011\ (50)\ (100)$$

$$P_L = 12.75 \text{ MW}$$

32. (c)

For optimal system operation,

$$\frac{dC_1}{dP_1} = \frac{dC_2}{dP_2}$$

$$0.20P_1 + 40 = 0.25P_2 + 30$$

$$0.20P_1 - 0.25P_2 = -10 \quad \text{...(i)}$$

and $$P_1 + P_2 = 250 \quad \text{...(ii)}$$

Solving (i) and (ii),

$$P_1 = \frac{350}{3}\text{MW},$$

$$P_2 = \frac{400}{3}\text{MW}$$

33. (b)

Given, $S = 100$ MVA , $f = 50$ Hz

$H = 10$ MJ/MVA,

$$P_a = P_m - P_e$$

$$= 80 - 40 = 40 \text{ MW}$$

From swing equation,

$$M\frac{d^2\delta}{dt^2} = P_m - P_e$$

$$\frac{HS}{180f} \cdot \frac{d^2\delta}{dt^2} = P_a$$

$$\frac{10\times 100}{180\times 50}\cdot\frac{d^2\delta}{dt^2} = (80 - 40)$$

$$\frac{d^2\delta}{dt^2} = \alpha = \frac{40\times 180\times 50}{10\times 100}$$

$$\alpha = 360°/\text{sec}^2$$

34. (d)

Given data are,

$$G_1 = 300 \text{ MVA}, \quad G_2 = 600 \text{ MVA}$$

$$H_1 = 2 \text{ sec}, \quad H_2 = 1 \text{ sec}$$

The intertia constant on base 500 MVA

$$H_{eq} = \frac{G_1H_1 + G_2H_1}{G_{base}} = \frac{(300\times 2)+(600\times 1)}{500}$$

$$= 2.4 \text{ sec}$$

35. (c)

Given that, $H = 7.85$ MJ/MVA

$P_e = 0.60$ of P_{max}

$$P_{max} = \frac{EV}{X} = \frac{1.3}{1+0.3} = 1$$

So, $P_e = 1 \sin\delta$

For $P_e = 0.60 \times 1 = 1 \sin\delta$

$$\delta = \sin^{-1}(0.6) = 36.86°$$

Now, $$S_p = \frac{dP_e}{d\delta} = P_{max}\cos\delta = \cos\delta$$

at $\delta = 36.86$, $$S_p\Big|_{s=s_0} = \cos(36.86) = 0.8$$

So, $$f = \frac{1}{2\pi}\sqrt{\frac{S_p}{M}} = \frac{1}{2\pi}\sqrt{\frac{0.8}{\frac{7.85\times 1}{\pi\times 50}}}$$

$$f = \frac{4}{2\pi} = 0.64 \text{ Hz}$$

36. (a)

As the transformer is the most costliest equipment in the substation, lightning arrester is placed near to it.

37. (d)

Without any series reactance,

The fault current, $I_F = \frac{1}{X}$

$$10 = \frac{1}{X}$$

$$X = 0.1$$

With series reactance, $I_F = 4 = \frac{1}{0.1 + X}$

$$X = \frac{1}{4} - 0.1 = 0.15 \text{ p.u.}$$

38. (b)

The p.u. impedance is $X = 0.242$ p.u.

So, $$X_{new} = X_{old} \times \left(\frac{V_{old}}{V_{new}}\right)^2 = 0.242 \times \left(\frac{1}{1.1}\right)^2 = 0.20$$

So, per unit admittance $= \frac{1}{0.20} = 5$ p.u.

39. (b)

The 3-ϕ short circuit current,

$$I_{SC} = \frac{V_{th}}{X_1} \quad \text{...(i)}$$

The single line to earth fault current

$$I_F = \frac{3V_{th}}{X_1 + X_2 + X_0 + 3X_n}$$

here, $X_1 = X_2$

So, $$I_F = \frac{3V_{th}}{2X_1 + X_0 + 3X_n}$$

Given, $I_F > I_{SC}$

$$\frac{3V_{th}}{2X_1 + X_0 + 3X_n} > \frac{V_{th}}{X_1}$$

$$3X_1 > 2X_1 + X_0 + 3X_n$$

$$3X_n < (X_1 - X_0)$$

$$X_n < \frac{1}{3}(X_1 - X_0)$$

40. (b)

The equivalent positive sequence for whole system,

$$X_{1\,eq} = \frac{0.2}{2} = 0.1 \text{ p.u.}$$

Similarly, $$X_{2\,eq} = \frac{0.2}{2} = 0.1 \text{ p.u.}$$

For zero sequence, $X_{0\,eq} = 0.10$ p.u.

Now zero sequence fault current,

$$I_{F0} = \frac{V_{th}}{X_1 + X_2 + X_0 + 3X_n} = \frac{1}{0.1+0.1+0.1+3\times 0.5}$$

$$= \frac{5}{9} \text{ p.u.}$$

Voltage across neutral, $X_n = V_n = I_{F0}(3X_n)$

$$= \frac{5}{9}(3\times 0.5)$$

$$V_n = 0.83 \text{ p.u.}$$

41. (d)

Given, $$Z_{TX} = 10\angle 60° = 10(\cos 60° + j \sin 60°)$$

$$= (5 + j5\sqrt{3})\Omega$$

Condition for maximum voltage regulation,

$$\cos\phi_R = \frac{R}{\sqrt{R^2+X^2}} = \frac{5}{\sqrt{\left(5\sqrt{3}\right)^2 + 5^2}} = 0.5 \text{ lagging}$$

Condition for zero voltage regulation,

$$\cos\phi_R = \frac{X}{\sqrt{R^2+X^2}} = \frac{5\sqrt{3}}{\sqrt{5^2 + \left(5\sqrt{3}\right)^2}}$$

$$= 0.87 \text{ leading}$$

42. (c)

Net reactance of parallel connection,

$$X = \frac{0.25}{5} = 0.05 \text{ p.u.}$$

$$I_{SC} = \frac{1}{X} = \frac{1}{0.05} = 20 \text{ p.u.}$$

$$\text{SC MVA} = 20 \times 5$$

$$= 100 \text{ MVA}$$

43. (c)

Statement-I is true but statement-II is false because A smoothing reactor is installed on the DC side to limit the harmonics.

44. (c)

Statement-I is true but statement-II is false.

The synchronizing coefficient,

$$S_p = \frac{dP_e}{d\delta} = \frac{EV}{X}\cos\delta$$

If $\delta > 90°$, $S_p < 0$ so system is unstable.

If $\delta < 90°$, $S_p > 0$ so system is stable

S_p shows the slope of power angle curve.

So statement-II is wrong.

45. (a)

Both assertion and reason are correct and reason given is correct explanation of assertion. GS method requires less time per iteration.

Section B : Electrical Machines-1

46. (a)

Because of the nonlinear effects of hysteresis the core-loss current is nonlinear.

47. (a)

$$E_1 = 3300 \text{ V}, \qquad E_2 = 250 \text{ V},$$

$$f = 50 \text{ Hz}$$

$$A = 125 \text{ cm}^2 = 125 \times 10^{-4} \text{ m}^2$$

$$E_2 = 4.44\, \phi_m f T_2 = 4.44\, B_m A f T_2$$

$$B_m = \frac{E_2}{4.44 A f T_2} = \frac{250}{4.44 \times 125 \times 10^{-4} \times 50 \times 70} = 1.289 \text{ T}$$

48. (c)

$$\frac{T_1}{T_2} = \frac{E_1}{E_2} = \frac{2000}{400} = 5$$

$$R_{e2} = R_2 + R_1\left(\frac{T_2}{T_1}\right)^2 = 0.2 + 5.5\left(\frac{1}{5}\right)^2 = 0.42\ \Omega$$

$$X_{e2} = X_2 + X_1\left(\frac{T_2}{T_1}\right)^2 = 0.45 + 12\left(\frac{1}{5}\right)^2 = 0.93\ \Omega$$

$$\text{KVA} = \frac{V_2 I_2}{1000}$$

$$I_2 = \frac{1000 \times \text{kVA}}{V_2} = \frac{1000 \times 10}{400} = 25 \text{ A}$$

Since, $\cos \phi_2 = 0.8$,

$\sin \phi_2 = 0.6$

$$E_2 = E_1 \times \frac{T_2}{T_1} = V_1 \times \frac{T_2}{T_1} = 2000 \times \frac{1}{5} = 400 \text{ V}$$

$$E_2 = V_2 + I_2 R_{e2} \cos \phi_2 + I_2 X_{e2} \sin \phi_2$$

$$V_2 = 400 - 25 \times 0.42 \times 0.8 - 25 \times 0.93 \times 0.6$$

$$= 377.65 \text{ V}$$

49. (b)

$S = 0.04$,

Stator input = 90 kW,

Stator loss = 2 kW

Air gap power, P_{ag} = Stator output = Stator input – Stator loss

= 90 – 2 = 88 kW

Mechanical power developed,

$$P_m = (1 - s)P_{ag} = 0.96 \times 88 = 84.48 \text{ kW}$$

50. (b)

The ratio of maximum torque to general torque is

$$\frac{T_m}{T} = \frac{\frac{s_m}{s} + \frac{s}{s_m}}{2}$$

$$\frac{400}{100} = \frac{s_m + \frac{1}{s_m}}{2} \qquad \text{(at starting, slips = 1)}$$

$$s_m + \frac{1}{s_m} = 8$$

$$s_m^2 - 8s_m + 1 = 0$$

$$s_m = 0.127$$

51. (c)

$$\frac{\text{Rotor gross output}}{\text{Rotor input}} = 1 - s = \frac{N}{N_s}$$

$$\frac{1800}{2000} = 1 - s$$

$$s = 0.1 \text{ or } 10\%$$

$$1 - 0.1 = \frac{810}{N_s}$$

$$N_s = 900 \text{ rpm}$$

$$f' = sf$$

$$6 = 0.1 \times f$$

$$f = 60 \text{ Hz}$$

$$900 = \frac{120 \times \frac{6}{0.1}}{P}$$

$$P = \frac{120 \times 60}{900} = 8$$

52. (a)

Maximum torque is obtained when

$$s_{\max,\,T} = \frac{R_2}{X_2} = \frac{\text{Rotor resistance}}{\text{Stand still rotor reatance}}$$

For maximum torque at starting,

$$s_{\max,\,T} = 1$$

$$R_2 = X_2$$

53. (d)

Starting current, $I_{st} = \dfrac{V_{\text{ph}}}{\sqrt{(r_2'')^2 + (x_2')^2}}$,

$$r_2'' = r_2' + r_{\text{ext}}$$

So, $I_{\text{st}} \downarrow$

$$\Rightarrow \quad T_{\max} = \frac{3}{\omega_s} \cdot \frac{V_{\text{ph}}^2}{2x_2}$$

Independent of rotor resistance, so $T_{\max}$ will remain same.

$$\Rightarrow \quad s_{mT} = \frac{(r_2' + r_{\text{ext}})}{x_2'}, \text{ as } r_2'' \uparrow, \text{ so } s_{mT} \uparrow$$

$$\Rightarrow \quad T_{st} = \frac{3}{\omega_s} \cdot \frac{V_{\text{ph}}^2 \cdot (r_2' + r_{\text{ext}})}{(r_2' + r_{\text{ext}})^2 + (x_2')^2}$$

at starting, $(r_2' + r_{\text{ext}}) << x_2'$

$$(r_2' + r_{\text{ext}})^2 << (x_2')^2$$

$$T_{st} \approx \frac{3}{\omega_s} \cdot \frac{V_{\text{ph}}^2 \cdot (r_2' + r_{\text{ext}})}{(x_2')^2}$$

So, starting torque will increases.

54. (a)

Given that,

$$r_2' = 4.5\ \Omega,$$

$$x_2' = 8.5\ \Omega$$

$$T_{st} = \frac{3}{\omega_s}\cdot\frac{V_{ph}^2 \cdot r_2'}{(r_2')^2 + (x_2')^2}$$

$$\omega_s = \frac{4\pi f}{P} = 50\pi = 157.1 \text{ rad/sec}$$

$$85 = \frac{3}{157.1}\cdot\frac{V_{ph}^2 \times 4.5}{(4.5)^2 + (8.5)^2}$$

$$V_{ph} = 302.48 \text{ V}$$

55. (d)

The synchronous speed of this motor is

$$n_s = \frac{120f}{P} = \frac{120\times 50}{4} = 1500 \text{ rpm}$$

The rotor speed of the motor is given by

$$n_m = (1 - s)n_s = (1 - 0.05) \times 1500$$
$$= 1425 \text{ rpm}$$

56. (d)

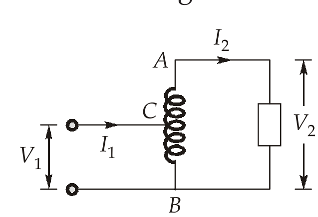
All statements are correct.

57. (c)

All statements are correct.

58. (b)

Maximum rating obtained when both the windings are connected in additive polarity.



The auto transformer is shown below:

The input voltage is 240 V,

Output voltage is 240 + 120 = 360 V

The maximum VA rating of auto transformer is V_2I_2

i.e. $\left(360\times\frac{200}{120}\right)$VA or 600 VA

59. (a)

$$\text{Primary line voltage} = 22000 \text{ V}$$
$$\text{Secondary line voltage} = 400 \text{ V}$$
$$\text{Primary phase voltage} = 22000 \text{ V}$$

Turns ratio are defined in phase to phase voltages

$$\text{Secondary phase voltage} = \frac{400}{\sqrt{3}}$$

$$\text{Turns ratio} = \left(\frac{V_{1ph}}{V_{2ph}}\right) = \frac{22000\sqrt{3}}{400} = 55\sqrt{3}$$

60. (d)

A double-cage induction motor has good starting characteristics.

Section C : Control Systems-2 + Engineering Mathematics-2

61. (a)

In lag compensation, the pole is nearer to origin compared to zero, hence the effect of pole is dominant.

62. (a)

For a system to be stable,
Gain crossover frequency < Phase crossover frequency.

63. (b)

For given system gain crossover frequency can be calculated as,

$$|G(j\omega)H(j\omega)|_{\omega=\omega_{gc}} = 1$$

$$\frac{100}{\omega_{gc}} = 1$$

$$\omega_{gc} = 100 \text{ r/sec}$$

64. (a)

A gain margin close to unity or a phase margin close to zero corresponds to a highly oscillatory system.

65. (c)

For the given system matrix A

$$[sI - A] = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} s-1 & -1 \\ 0 & s-1 \end{bmatrix}$$

$$\therefore \qquad \phi(s) = [sI - A]^{-1} = \frac{\text{adj}[sI - A]}{|sI - A|}$$

$$= \frac{1}{(s-1)^2}\begin{bmatrix} s-1 & 1 \\ 0 & s-1 \end{bmatrix}$$

∴ state transition equation $= \phi(t)$

$$= L^{-1}[\phi(s)]$$

$$= L^{-1}\begin{bmatrix} \frac{1}{s-1} & \frac{1}{(s-1)^2} \\ 0 & \frac{1}{s-1} \end{bmatrix} = \begin{bmatrix} e^t & te^t \\ 0 & e^t \end{bmatrix}$$

66. (a)

Given the matrices A, B and C

$$\begin{bmatrix} A & B \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ -3 & -2 \end{bmatrix}\begin{bmatrix} 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \\ -2 \end{bmatrix}$$

$$Q_C = \begin{bmatrix} B & AB \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 1 & -2 \end{bmatrix} = -1 \neq 0 \text{ so, system is controllable}$$

$$C^T = \begin{bmatrix} 1 \\ 0 \end{bmatrix},$$

$$A^T C^T = \begin{bmatrix} 1 & -3 \\ 1 & -2 \end{bmatrix}\begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

$$Q_C = \begin{bmatrix} C^T & A^T C^T \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix} = 1 \neq 0 \text{ the system is completely observable}$$

67. (c)

For absolute stable,

$$\omega_{gc} < \omega_{pc}$$

or $$\omega_{pc} > \omega_{pc}$$

$$\frac{\omega_{pc}}{\omega_{gc}} > 1$$

$$5\,K > 1$$

$$K > 0.2$$

So, all the values of $K > 0.2$ makes system stable.

68. (d)

$$20 \log K + 20 \log 10 = 20$$

$$\Rightarrow \quad K = 1$$

The transfer function of the bode plot shown below is

$$= \frac{s}{\left(1+\frac{s}{10}\right)\left(1+\frac{s}{100}\right)} = \frac{1000s}{(s+10)(s+100)}$$

69. (a)

$$\cos\frac{1}{z} = 1 - \frac{1}{2!}\left(\frac{1}{z^2}\right) + \frac{1}{4!}\left(\frac{1}{z^4}\right) + \ldots$$

$$z\cos\left(\frac{1}{z}\right) = z - \frac{1}{2!}\left(\frac{1}{z}\right) + \frac{1}{4!}\left(\frac{1}{z^3}\right) + \ldots$$

Residue of $f(z)$ at $z = 0$, is the coefficient of $\frac{1}{z}$ i.e.

$$\frac{-1}{2!} = \frac{-1}{2 \times 1} = -0.5$$

70. (c)

Comparing the given equation with the general form of second order partial differential equation,

We have, $A = 1$, $B = 3$, $C = 2$

$$B^2 - 4AC = 1 > 0$$

∴ Partial differential equation is Hyperbolic.

71. (c)

$$y = 0.516x + 33.73 \quad \ldots(i)$$

$$x = 0.512x + 32.52 \quad \ldots(ii)$$

$$r\frac{\sigma_y}{\sigma_x} = 0.516 \quad \ldots(iii)$$

$$r\frac{\sigma_x}{\sigma_y} = 0.512 \quad \ldots(iv)$$

From (iii) and (iv),

$$\left(r\frac{\sigma_y}{\sigma_x}\right)\left(r\frac{\sigma_x}{\sigma_y}\right) = (0.516)\ (0.512) = 0.2641$$

$$r^2 = 0.516 \times 0.512$$

$$r = 0.514$$

Coefficient of correlation = 0.514

72. (c)

$P = 1\% = 0.01, \qquad n = 100,$

$$m = np = 100 \times 0.01 = 1$$

$$P(r) = \frac{e^{-m}\cdot(m)^r}{r!} = \frac{e^{-1}(1)^r}{r!} = \frac{e^{-1}}{r!}$$

P (4 or more faulty condensers) $= P(4) + P(5) + ... + P(100)$

$$= 1 - [P(0) + P(1) + P(2) + P(3)]$$

$$= 1-\left[\frac{e^{-1}}{0!}+\frac{e^{-1}}{1!}+\frac{e^{-1}}{2!}+\frac{e^{-1}}{3!}\right]$$

$$= 1-e^{-1}\left[1+1+\frac{1}{2}+\frac{1}{6}\right] = 1-\frac{8}{3e}$$

73. (c)

Two boys are to be selected out of 5 boys. A particular boy A is to be included in the committee. It means that only 1 boy is to be selected out of 4 boys

Number of ways of selection = $^4C_1$

Similalry a girl B is to be included in the committee then only 3 girls are to be selected out of 5 girls

Number of ways of selection = $^5C_3$

$$\text{Required probability} = \frac{^4C_1 \times {}^5C_3}{^5C_2 \times {}^6C_4} = \frac{4\times 10}{10\times 15} = \frac{4}{15}$$

74. (b)

Let, $\qquad f(x) = e^{\sin x}$

$$f'(x) = e^{\sin x}\cos x = f(x)\cdot\cos x$$

Also, $\qquad e^{\sin x} = 1+\sin x+\frac{(\sin x)^2}{2!}+\frac{(\sin x)^3}{3!}+\frac{(\sin x)^4}{4!}+....$

$$= 1+\left(x-\frac{x^3}{3!}+...\right)+\frac{1}{2!}\left(x-\frac{x^3}{3!}+....\right)^2+\frac{1}{3!}\left(x-\frac{x^3}{3!}+....\right)^3+....$$

$$= 1+\left(x-\frac{x^3}{6}+....\right)+\frac{1}{2}\left(x^2-\frac{x^4}{3}+....\right)+\frac{1}{6}\left(x^3-....\right)+\frac{1}{24}(x^4+...)+...$$

$$= 1+x+\frac{x^2}{2}-\frac{x^4}{8}+....$$

75. (a)

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