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ESE 2020 : 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.**	(b)	**31.**	(c)	**46.**	(d)	**61.**	(d)
2.	(c)	**17.**	(c)	**32.**	(a)	**47.**	(b)	**62.**	(d)
3.	(d)	**18.**	(c)	**33.**	(d)	**48.**	(c)	**63.**	(a)
4.	(c)	**19.**	(d)	**34.**	(b)	**49.**	(c)	**64.**	(b)
5.	(d)	**20.**	(c)	**35.**	(c)	**50.**	(d)	**65.**	(d)
6.	(b)	**21.**	(c)	**36.**	(d)	**51.**	(d)	**66.**	(a)
7.	(a)	**22.**	(b)	**37.**	(b)	**52.**	(d)	**67.**	(b)
8.	(a)	**23.**	(a)	**38.**	(a)	**53.**	(b)	**68.**	(a)
9.	(d)	**24.**	(b)	**39.**	(c)	**54.**	(b)	**69.**	(c)
10.	(b)	**25.**	(a)	**40.**	(a)	**55.**	(d)	**70.**	(c)
11.	(a)	**26.**	(c)	**41.**	(c)	**56.**	(a)	**71.**	(c)
12.	(c)	**27.**	(c)	**42.**	(b)	**57.**	(d)	**72.**	(b)
13.	(d)	**28.**	(c)	**43.**	(b)	**58.**	(c)	**73.**	(a)
14.	(a)	**29.**	(a)	**44.**	(d)	**59.**	(b)	**74.**	(c)
15.	(d)	**30.**	(d)	**45.**	(c)	**60.**	(b)	**75.**	(d)

DETAILED EXPLANATIONS
Section A : Power Systems

1. **(c)**

Voltage levels limits within close tolerances can be achieved by proper scheduling of reactive powers.

2. **(c)**

Net reactance of parallel connection,

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

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

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

$$= 100 \text{ MVA}$$

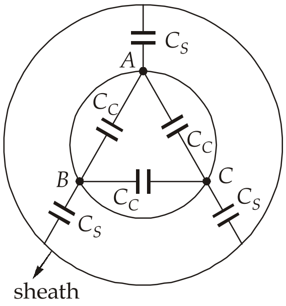
3. **(d)**

- Secondary loop of ALFC is used to maintain the fine adjustment of the frequency and also by reset action maintains proper MW interchange.
- Function of AVR is to provide constant terminal voltage during normal, slow and small changes in the load.

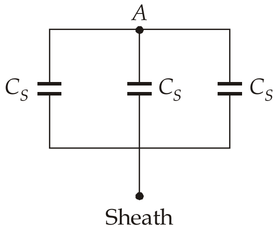
All statements are correct.

4. **(c)**

When all conductors are shorted,



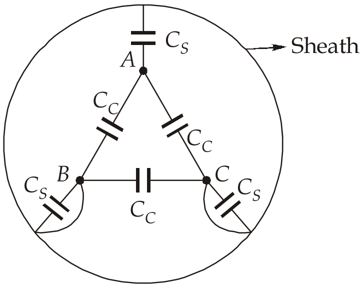
Capacitance between shorted conductors and sheath is $3C_s$.



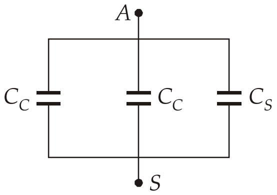
$\therefore$ $$3C_s = 0.8\ \mu\text{F}$$

$$C_s = \frac{0.8\mu\text{F}}{3} = 0.2667\ \mu\text{F}$$

When two conductors shorted with sheath



∴



$$C_{AS} = 2C_C + C_S$$

∴ Capacitance between two conductors shorted with sheath and the third conductor is $2C_C + C_S$.

∴ $$2\,C_C + C_S = 0.4$$
$$2C_C + 0.2667 = 0.4$$
$$2C_C = 0.1333$$
$$C_C = 0.0666\ \mu\text{F}$$

5. **(d)**

Under the influence of the damper winding, the generator is oscillatorily stable meaning that if subjected to any small disturbances it will return to its steady-state equilibrium by a damped oscillation.

6. **(b)**

$$R_I = -\frac{(Z_2 - Z_1)}{Z_2 + Z_1} = -\left(\frac{0 - Z_1}{0 + Z_1}\right) = 1$$

$$R_V = -R_I = -1$$

i.e. Reflection coefficient of voltage and current are –1 and 1 respectively for receiving end to be short circuited.

7. **(a)**

Terminal equipments are costly in HVDC.

8. **(a)**

$$\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{0.00127} = 4947.39 \text{ km}$$

$$\text{Ratio} = \frac{\text{line length}}{\text{wave length}} = \frac{300 \text{ km}}{4947.39 \text{ km}} = 0.0606$$

$$\%\text{ratio} = 6.06\%$$

9. (d)

Methods to improve transient stability of power system:

- High inertia constant.
- increasing system voltage
- reducing transfer reactance by using series capacitors.
- high speed excitation system.
- load shedding.

For given question all mentioned methods are employed to improve transient stability.

10. (b)

- An over currents relay is said to over reach when it operates at a current lower than its setting.
- Short circuit current is highest possible fault current that can be experienced. Hence normally, earth fault current is lesser value.

11. (a)

Inner radius, $r = \frac{1}{2}\text{cm} = 0.5 \text{ cm}$

Insulation thickness, $t = 1.5 \text{ cm} = R - r$

Outer radius, $R = t + r = 1.5 + 0.5 = 2.0$

$$E_{\max} = \frac{V}{r\ln\left(\frac{R}{r}\right)} = \frac{33\times10^3}{0.5\ln\left(\frac{2}{0.5}\right)} \approx 47600 \text{ V/cm}$$

12. (c)

$$X_{\text{p.u. new}} = X_{\text{p.u. old}}\left(\frac{\text{MVA}_{b\text{new}}}{\text{MVA}_{b\text{old}}}\right)\left(\frac{\text{kV}_{b\text{old}}}{\text{kV}_{b\text{new}}}\right)^2$$

$$= 0.25\times\left(\frac{100}{500}\right)\left(\frac{18}{20}\right)^2 = 0.0405 \text{ p.u.}$$

13. (d)

All of the above are advantages of oil filled cables.

14. (a)

Voltage across the circuit breaker contacts after the interruption of 10 A current

$$V = i\sqrt{\frac{L}{C}} = 10\sqrt{\frac{5}{0.01\times10^{-6}}} = 10\sqrt{5}\times10^4 = 100\sqrt{5}\text{ kV}$$

15. (d)

- Convergence can be speed up by the use of acceleration factor in Gauss Siedel method. This may led to reduction in number of iterations.
- DLF method have 30% - 40% saving as compared to Newton Raphson method in storing Jacobian matrix.
- Sum of elements of row of Y_{bus} matrix is zero if no shunt admittance is there.

16. (b)

$$\text{Given, } V_s = 120 \text{ kV}, \quad V_r = 110 \text{ kV}, \quad A = 0.96, \quad \alpha = 10°, \quad B = 100, \quad \beta = 80°$$

Maximum power transmitted is given by,

$$P_{\max} = \frac{V_s \cdot V_r}{B} - \frac{AV_r^2}{B}\cos(\beta - \alpha)$$

$$= \frac{110 \times 120}{100} - \frac{0.96 \times (110)^2}{100}\cos(80° - 10°)$$

$$P_{\max} = 92.27 \text{ MW}$$

17. (c)

Under frequency operation may lead to over fluxing in a power transformer, hence it is undesirable. Both statements are correct.

18. (c)

Primary earth-fault current at which the relay operates,

$$= \frac{100 \times 10^6}{\sqrt{3} \times 11 \times 10^3} \times \frac{15}{100} = 787.29 \text{ A}$$

The percentage of winding which remains unprotected is

$$P = 100 - 80 = 20\%$$

$$\text{The fault current } = \frac{20}{100} \times \frac{11 \times 10^3}{\sqrt{3}R_n}$$

Where R_n is the resistance in the neutral to ground connection

$$\frac{20}{100} \times \frac{11 \times 10^3}{\sqrt{3}R_n} = 787.29$$

$$\therefore \quad R_n = \frac{20 \times 11 \times 10^3}{100 \times \sqrt{3} \times 787.29} = 1.61 \text{ ohms}$$

19. (d)

All the statements are correct.

20. (c)

Reactive power of capacitor,

$$Q_C \propto V^2\omega$$

$$Q_C \propto V^2 f$$

$$\therefore \text{ Reactive power supplied } = \left(\frac{1.1 \times 33}{33}\right)^2 \times \left(\frac{0.85 \times f}{f}\right) \times 100$$

$$= 102.85 \text{ MVAR}$$

21. (c)

Since the generators are in parallel, they will operate at the same frequency at steady load. Let load on generator G_1 is P_{G1} , and load on generator G_2 is P_{G2}.

If Δf is the change in frequency,

then,
$$\frac{\Delta f}{P_{G1}} = \frac{0.04 \times 50}{200} \quad \text{...(i)}$$

$$\frac{\Delta f}{600 - P_{G1}} = \frac{0.05 \times 50}{400} \quad \text{...(ii)}$$

From equation (i),

$$\frac{\Delta f}{P_{G1}} = 0.01$$

$$\Delta f = 0.01 \times P_{G1} \quad \text{...(iii)}$$

From second equation, $\Delta f = \frac{1}{160}(600 - P_{G1})$ ...(iv)

From equation (iii) and (iv), we get

$$\frac{P_{G1}}{100} = \frac{600 - P_{G1}}{160}$$

$$16\, P_{G1} = 6000 - 10\, P_{G1}$$

$$26\, P_{G1} = 6000$$

$$P_{G1} = 230.76 \text{ MW}$$

$$\therefore \quad P_{G2} = 600 - 230.76 = 369.23 \text{ MW}$$

22. (b)

For the fully transposed transmission line,

Positive sequence impedance $Z_1 = Z_s - Z_m$

Negative sequence impedance $Z_2 = Z_s - Z_m$

Zero sequence impedance, $Z_0 = Z_s + 2Z_m + 3Z_n$

Where, Z_s = Self impedance/ph

Z_m = Mutual impedance/ph

If the system voltages are unbalanced, we have a neutral current, I_n flowing through the neutral (ground) having impedance Z_n.

From above equations, we can say

1. Positive and negative sequence impedance are equal.
2. Zero sequence impedance is much larger than the positive or negative sequence impedance.

$\therefore$ Statement (I) is true and statement (II) is false.

23. (a)

Number of units, $n = 3$

Ratio of shunt capacitance to self capacitance,

$$K = \frac{0.15C}{C} = 0.15$$

Voltage across bottom most unit,

$$V_3 = \text{safe working voltage of the unit} = 20 \text{ kV}$$

So voltage across top most unit,

$$V_1 = \frac{V_3}{1+3K+K^2} = \frac{20}{1+3(0.15)+(0.15)^2} = \frac{20}{1.4725}$$

$$V_1 = 13.58 \text{ kV}$$

Voltage across middle unit,

$$\begin{aligned} V_2 &= V_1(1+K) \\ &= (13.58 \text{ kV})\ (1+0.15) \\ &= 15.617 \text{ kV} \end{aligned}$$

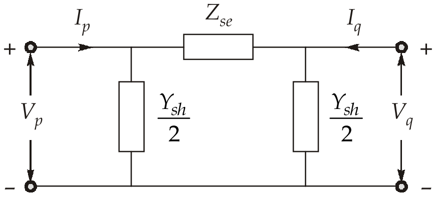
Maximum safe working voltage of the string,

$$\begin{aligned} V &= V_1 + V_2 + V_3 \\ &= 13.58 + 15.617 + 20 \\ V &= 49.197 \text{ kV} \end{aligned}$$

$$\text{String efficiency} = \frac{V}{nV_n} \times 100 = \frac{49.197}{3 \times 20} \times 100 = 81.995 \approx 82\%$$

24. (b)

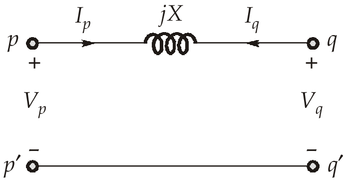
Y-bus matrix for the π equivalent circuit.



$$Y_{\text{bus}} = \begin{bmatrix} \frac{1}{Z_{se}} + \frac{Y_{\text{sh}}}{2} & -\frac{1}{Z_{se}} \\ -\frac{1}{Z_{se}} & \frac{1}{Z_{se}} + \frac{Y_{\text{sh}}}{2} \end{bmatrix}$$

Here, $Z_{\text{se}} = jX;\ Y_{\text{sh}} = 0$

The above circuit diagram becomes,



$$\therefore \qquad Y_{\text{bus}} = \begin{bmatrix} \frac{1}{jX} & \frac{-1}{jX} \\ \frac{-1}{jX} & \frac{1}{jX} \end{bmatrix}$$

25. (a)

Let the operating voltage and power factor in both the systems be V volts and $\cos\phi$ respectively. If I_1 is single phase current, I_2 is the three phase current and R is the resistance of each conductor, then

Single phase system:

$$P_1 = VI_1 \cos\phi \text{ Watts}$$

$$\text{Losses} = 2I_1^2 R \text{ Watts}$$

$$\text{Percentage line losses} = \frac{W_1}{P_1}\times 100 = \frac{2I_1^2R}{VI_1\cos\phi}\times 100$$

3-ϕ system:

$$P_2 = \sqrt{3}VI_2\cos\phi$$

$$\text{Line losses} = 3I_2^2R$$

$$\text{Percentage line losses} = \frac{3I_2^2R}{\sqrt{3}VI_2\cos\phi}\times 100$$

For the same percentage line losses in both the cases, we have

$$\frac{2I_1^2R}{VI_1\cos\phi}\times 100 = \frac{3I_2^2R}{\sqrt{3}VI_2\cos\phi}\times 100$$

$$2I_1 = \sqrt{3}I_2$$

$$I_2 = \frac{2}{\sqrt{3}}I_1$$

∴ Power transmitted in 3-ϕ system,

$$P_2 = \sqrt{3}V\times\frac{2}{\sqrt{3}}I_1\cos\phi = 2VI_1\cos\phi = 2P_1$$

∴ Percentage of additional load

$$= \frac{P_2-P_1}{P_1}\times 100 = \frac{P_1}{P_1}\times 100 = 100\%$$

26. (c)

Minimum number of equations

$$= 2n - m - 2 = 2(112) - 20 - 2 = 202$$

27. (c)

In case of current leaving the protected zone is zero.

$$I_{2s} = 0$$

$$\text{The differential current} = I_{1s} - I_{2s} = I_{1s}$$

$$\text{Through current} = \frac{I_{1s}+I_{2s}}{2} = \frac{I_{1s}}{2}$$

∴ The slope of the internal fault characteristics is

$$= \frac{I_{1s}-I_{2s}}{\frac{(I_{1s}+I_{2s})}{2}} = 2$$

28. (c)

Maximum dielectric stress = $g_{\max}$

$$g_{\max} = \frac{V}{r\ln\left(\frac{R}{r}\right)}$$

Minimum dielectric stress = $g_{\min}$

$$g_{\min} = \frac{V}{R\ln\left(\frac{R}{r}\right)}$$

∴ the ratio of maximum to minimum dielectric stress

$$= \frac{g_{\max}}{g_{\min}}$$

(or)

$$\frac{g_{\max}}{g_{\min}} = \frac{\dfrac{V}{r\ln\left(\frac{R}{r}\right)}}{\dfrac{V}{R\ln\left(\frac{R}{r}\right)}} = \frac{R}{r} = \frac{D}{d}$$

29. (a)

For given transmission line,

Positive sequence reactance, $x_1 = X_s - X_m$

$= 0.5 - 0.2$

$= 0.3\ \Omega/\text{km}$

Zero sequence reactance, $x_0 = X_s + 2X_m$

$= 0.5 + 0.2 \times 2$

$= 0.9\ \Omega/\text{km}$

30. (d)

Given, series impedance: $(0 + j0.5)\ \Omega/\text{km}$

For 500 km : $j250\ \Omega$

Similarly,

shunt admittance = $(0 + j5)\ \mu$ mho/km

for 500 km : $(0 + j5) \times 10^{-6} \times 500 = (0 + j2.5 \times 10^{-3})\ \mho$

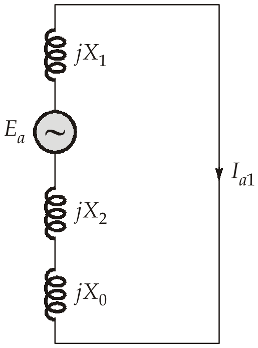
Characteristic impedance,

$$Z_C = \sqrt{\frac{Z}{Y}}$$

$$Z_C = \sqrt{\frac{250}{2.50 \times 10^{-3}}} = 316.22\ \Omega$$

31. **(c)**

For a line to ground fault,
Positive sequence current,



$$I_{a1} = \frac{E_a}{Z_1 + Z_2 + Z_0}$$

$$I_{a1} = \frac{1}{j0.25 + j0.35 + j0.1} = -j1.428$$

$$\text{Base current, } I_B = \frac{25 \times 1000 \times 10^3}{\sqrt{3} \times 13.2 \times 10^3} = 1093.46 \text{ A}$$

$$\text{Fault current, } I_f = 3I_{a1} \times I_b$$

$$= 3 \times 1.428 \times 1093.46$$

$$= 4684.38 \text{ A}$$

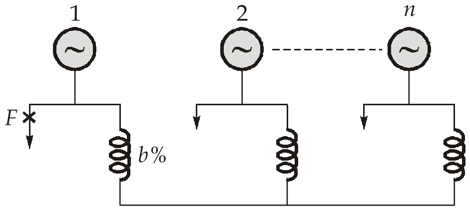
32. **(a)**

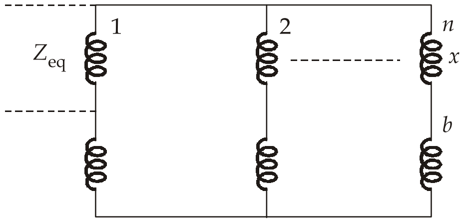
$X_{L,\,\text{sh}}$ under no-load condition

$$= \frac{B}{1-A} = \frac{150\angle 90^\circ}{1-0.9} = j1500\ \Omega$$

$$X_{L,\,\text{sh}} = 1500\angle 90^\circ\ \Omega$$

33. **(d)**





Equivalent impedance Z_{eq} between the zero potential bus and the fault point is

$$\left(\frac{b+x}{n-1} + b\right) \| x = \left(\frac{bn+x}{n-1}\right) \| x$$

$$\frac{1}{Z_{\text{eq}}} = \frac{1}{x} + \frac{n-1}{bn+x}$$

$$\text{SC kVA} = \frac{8}{Z_{\text{eq}}} \times 100$$

$$= 8\left[\frac{1}{x}+\frac{n-1}{bn+x}\right]\times 100$$

If n is very large.

$$\text{Short circuit kVA} = 8\left[\frac{1}{x}+\frac{1}{b}\right]$$

34. (b)

$$\delta_0 = \sin^{-1}\left(\frac{P_e}{P_m}\right) = \sin^{-1}(0.5) = 30°$$

$$P_e = \frac{EV}{X}\sin\delta_0$$

$$\frac{dP_e}{d\delta} = \frac{EV}{X}\cos\delta_0 = \frac{1.2\times 1}{1.8}\cos 30°$$

$$= 0.577 \text{ MW (p.u.)/elec. rad}$$

$$M = \frac{GH}{\pi f} = \frac{1\times 4}{\pi\times 50} = 0.025 \text{ s}^2/\text{elec. rad}$$

$$\omega = \left(\frac{\left(\frac{dP_e}{d\delta_0}\right)}{M}\right)^{1/2} = \left(\frac{0.577}{0.025}\right)^{1/2} = 4.8 \text{ rad/sec}$$

Frequency of natural oscillation,

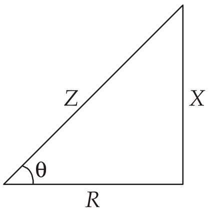
$$f = \frac{\omega}{2\pi} = 0.764 \text{ Hz}$$

35. (c)

Given, $|V_S| = |V_R| = 115 \times 10^3$ volts

$$P_{R,\,\max} = \frac{|V_R||V_S|}{|Z|} - \frac{|V_R|^2}{|Z|}\cos\theta$$

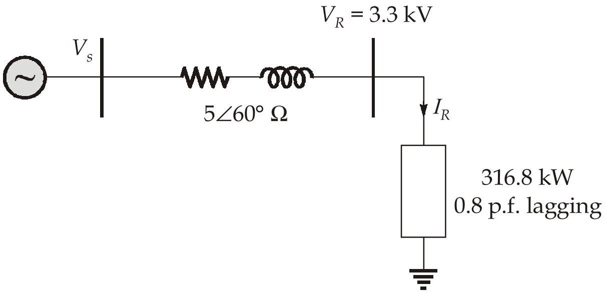
$$\cos\theta = \frac{R}{Z}.$$



$$P_{R\,,\,\max} = \frac{|V_R||V_S|}{|Z|} - \frac{|V_R|^2 R}{|Z|^2}$$

$$= \frac{(115\times 10^3)^2}{\sqrt{4^2+7^2}} - \frac{(115\times 10^3)^2\times 4}{4^2+7^2} = 826.51 \text{ MW}$$

36. (d)



$$\vec{I}_R = \frac{316.8\times 10^3}{3300\times 0.8}\angle -\cos^{-1}(0.8)\ \text{A}$$

$$\vec{I}_R = 120\angle -36.8698°\ \text{A}$$

$$\vec{V}_s = \vec{V}_R + \vec{I}_R\vec{Z}_L$$

$$\vec{V}_s = 3300\angle 0° + (5\angle 60°)(120\angle -36.8698°) = 3858.97\angle 3.501°\ \text{V}$$

$$\text{Voltage regulation} = \frac{|V_s|-|V_R|}{|V_R|}\times 100 = \frac{3858.97-3300}{3300}\times 100$$

$$\% V\cdot R = 16.94\%$$

37. (b)

For 345 kV lines,

$$\text{SIL} = \frac{345^2}{297} = 401\ \text{MW}$$

Now,
$$P = V_{S\,\text{p.u.}}\cdot V_{R\,\text{p.u.}}(SIL)\cdot\frac{\sin\delta}{\sin\left(\frac{2\pi l}{\lambda}\right)}W$$

$$P = \frac{(1.0)(0.95)(401)\sin 35°}{\sin\left(\frac{2\pi\times 500}{5000}\right)} = (401)\ (0.927) = 372\ \text{MW/line}$$

In order to transmit 9000 MW with one line out of service

$$\text{Number of 345 kV lines} = \frac{9000\ \text{MW}}{372\ \text{MW/line}} + 1 = 24.2 + 1 \approx 26$$

38. (a)

We know that,
$$\lambda = \frac{(dC/dP)}{1-\frac{dP_{\text{Loss}}}{dP}} = \frac{0.012P+8}{1-0.2}$$

$$25\times 0.8 = 0.012P + 8$$

The power generation, $P = 1000$ MW

39. (c)

Generalized constants of two lines combined in parallel are:

$$A = \frac{A_1 B_2 + A_2 B_1}{B_1 + B_2} = 0.98\angle 1^\circ$$

$$B = \frac{B_1 B_2}{B_1 + B_2} = 50\angle 75^\circ\ \Omega$$

40. (a)

The p.u. three-phase fault current at Bus-2 is

$$= I_{f\,3-\phi} = \frac{1}{Z_{22}} = \frac{1}{j1.50} = 0.667\angle{-90^\circ}\text{ p.u.}$$

41. (c)

Thermal time constant is of the order of several minutes.

42. (b)

- In AC transmission, both the magnitude and phase of the bus voltage determine the power flow direction.
- While in HVDC, power transfer is governed only by the magnitudes of terminal voltages at two ends.

Both statements are true but statement-II is not the explanation of statement-I.

43. (b)

$$\text{SC MVA}_{\text{p.u.}}\text{ (3 phase)} = |V|_{\text{pre fault}} \times |I_{SC\text{ p.u.}}|$$

Both statements are true but statement-II is not the explanation of statement-I.

44. (d)

Load flow studies are usually carried out using Y_{bus} matrix, because its sparsity is very high.

45. (c)

The steady state power limit of salient pole machines occurs at smaller angle θ as compared to that of round rotor machine.

Section B : Electrical Machines-1

46. (d)

Synchronous speed of induction motor,

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

$$\text{slip, } s = \frac{f_r}{f_s} = \frac{2}{50} = 0.04$$

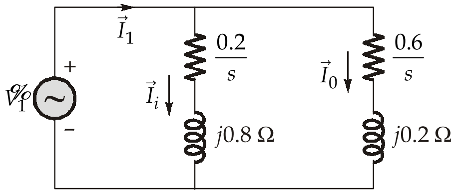
$$N_r = N_s(1 - s) = 1500(1 - 0.04) = 1440\text{ rpm}$$

$$P_0 = \tau \times \omega_m$$

$$= \frac{600 \times 1440 \times 2\pi}{60} = 28.8\,\pi\text{ kW}$$

47. (b)

The rotor currents in the inner and the outer cages are



$$\bar{I}_i = \frac{V_1}{\frac{0.2}{s} + j0.8}$$

and

$$\bar{I}_0 = \frac{V_1}{\frac{0.6}{s} + j0.2}$$

The torque developed by a three-phase induction motor is

$$T_d = \frac{3I_2^2 R_2}{s\omega_s}$$

thus, ratio of the torques developed by two cages is:

$$\frac{T_0}{T_i} = \frac{I_0^2 R_0}{I_i^2 R_i} = \frac{\left(\frac{0.2}{s}\right)^2 + (0.8)^2}{\left(\frac{0.6}{s}\right)^2 + (0.2)^2} \times \frac{0.6}{0.2}$$

On substituting, $s = 1$ we obtain

$$T_0 = 5.1\ T_i$$

48. (c)

Detent torque is the torque that motor produces when it is not energized and no current is flowing through the windings.

Holding torque is amount of torque that motor produces when it has rated current flowing through the winding but the motor is at rest.

49. (c)

For single phase induction motor,

Rotor resistance at stand still condition,

$$R_2 = 5.85\ \Omega$$

$$\text{Synchronous speed, } N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 \text{ rpm}$$

$$\text{Slip, } s = \frac{N_s - N_r}{N_s} = \frac{1500 - 1425}{1500} = \frac{75}{1500} = 0.05$$

Slip of the rotor w.r.t backward field,

$$= 2 - s = 2 - 0.05 = 1.95$$

Effective rotor resistance,

$$\frac{R_2}{2(2-s)} = \frac{5.85}{2\times 1.95} = 1.5\ \Omega$$

50. **(d)**

All statements are correct individually.

51. **(d)**

All given statements are correct.

52. **(d)**

$$\text{Maximum torque, } T_m = \frac{3}{\omega_s}\left[\frac{V^2}{2X_2'}\right]$$

i.e. $T_m \propto \dfrac{1}{X_2'}$

At low slip, $T \propto s$

$\because$ $T \propto \dfrac{sV^2}{R_2}$

Hence for constant torque, $s \propto R_2$ thus if rotor resistance increases, slip will also increase.

53. **(b)**

For 200 kVA, 50 Hz transformer

Core loss occurring in the transformer,

$$P_i = 300\text{ W}$$

Full load copper loss, $P_{cu} = I_{fL}^2 R = 800$ W (given)

Leakage reactance = 0.032 p.u.

$$\text{Winding resistance in per unit} = \frac{I^2R}{\text{kVA}}$$

$$= \frac{800}{200\times 1000} = \frac{4}{1000} = 0.004\text{ p.u.}$$

Losses occurring in transformer at 1.2 p.u. load,

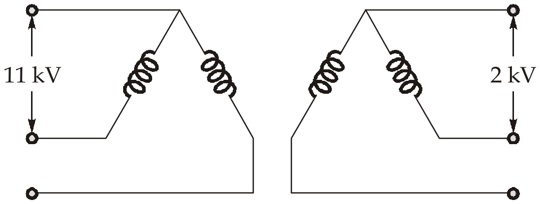
$$\begin{aligned} &= P_i + P_{cu} \\ &= 300 + (1.2)^2 \times 800 \\ &= 300 + 1.44 \times 800 \\ &= 300 + 1152 \\ &= 1452\text{ W} \end{aligned}$$

Per unit voltage regulation,

$$\begin{aligned} \text{V.R.} &= K(R_{pu}\cos\theta + X_{pu}\sin\theta) \\ &= 1.2\,(0.004 \times 0.8 + 0.032 \times 0.6) \\ &= 1.2\,(0.0032 + 0.0192) \\ &= 1.2(0.0224) \\ &= 0.02688\text{ p.u. or } 2.68\% \end{aligned}$$

54. (b)

Transformer connection in open delta will we



The secondary phase current,

$$I_{\text{ph sec}} = \frac{\text{kVA on secondary side}}{\text{kV on secondary side}} = \frac{250}{2} = 125 \text{ A}$$

Power transferred in open delta connection

$$= \sqrt{3}VI_{\text{ph}} = \sqrt{3} \times 125 \times 2 \approx 433 \text{ kVA}$$

Alternative Solution :

Consider 3-ϕ transformer bank

KVA rating of bank = 3 × 250 = 750 kVA

On connecting in open delta:

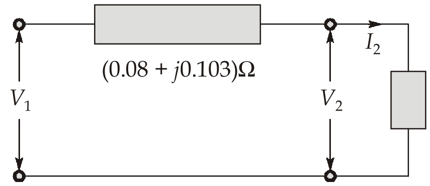
750 × 0.577 = 432.75 ≈ 433 kVA

55. (d)

By referring values on LV side of transformer,

Net resistance, $R_{\text{LV}} = 0.05 + \frac{3}{100} = 0.08\ \Omega$

Net reactance, $X_{\text{LV}} = 0.05 + \frac{5.3}{100} = 0.103\ \Omega$



Also, $I_2 = \frac{\text{kVA}}{200} = \frac{20 \times 1000}{200} = 100 \text{ A}$

At unity power factor,

$\cos\phi = 1$

$$\text{Voltage drop} = I(R_{\text{p.u.}}\cos\phi + X_{\text{p.u.}}\sin\phi)$$

$$= 100\ (0.08 \times 1 + 0.103 \times 0) = 8 \text{ V}$$

$$\text{Voltage regulation} = \frac{\text{Voltage drop}}{\text{Total voltage}} \times 100$$

$$= \frac{8}{200} \times 100 = 4\%$$

56. (a)

Efficiency of transformer,

$$\eta = \frac{\text{KVA}}{\text{KVA} + P_i + P_{cu}}$$

$$\frac{500}{500 + P_i + P_{\text{cu}}} = 0.90$$

$$500 = 0.90(500 + P_i + P_{\text{cu}})$$

$$50 = 0.9\ P_i + 0.9\ P_{\text{cu}}$$

$$\frac{50}{0.9} = P_i + P_{\text{cu}} \qquad \text{...(i)}$$

Similarly for 60% of full load

$$0.90 = \frac{300}{300 + P_i + 0.36 P_{cu}}$$

$$0.9(300 + P_i + 0.36\ P_{\text{cu}}) = 300$$

$$0.9\ P_i + 0.36 \times 0.9\ P_{\text{cu}} = 30$$

$$P_i + 0.36\ P_{\text{cu}} = \frac{30}{0.9} \qquad \text{...(ii)}$$

Simultaneously solving equation (i) and (ii), we get

$$P_i + P_{\text{cu}} = \frac{500}{9}$$

$$P_i + 0.36\ P_{\text{cu}} = \frac{300}{9}$$

$$0.64\ P_{\text{cu}} = \frac{200}{9}$$

$$P_{\text{cu}} = \frac{200 \times 100}{64 \times 9} = 34.72\ \text{W}$$

$$P_i = 20.84\ \text{W}$$

57. (d)

For back to back test,

Power input from supply line = total core loss of both transformers

$$\therefore \quad \text{core loss of each unit} = \frac{\text{Total core loss}}{2} = \frac{720\,\text{W}}{2} = 360\ \text{W}$$

Power consumed in the secondaries = total copper loss

$$\text{Ohmic loss of each transformer} = \frac{1280}{2} = 640\ \text{W}$$

Efficiency of each transformer at upf,

$$\frac{\text{kVA} \times \text{p.f.}}{\text{kVA} \times \text{p.f.} + P_c + P_{sc}} \times 100 = \frac{60 \times 1000 \times 1}{60 \times 1000 \times 1 + 360 + 640}$$

$$= \frac{60000}{61000} = 0.9836 \text{ or } 98.36\%$$

58. **(c)**

For primary induced emf in transformer

$$E_1 = 4.44\,\phi_m \times f \times N_1$$

$$E_1 = 4.44 \times B_m \times A_C \times f \times N_1 \qquad \text{... as } (\phi_m = B_m A_C)$$

Where, B_m = maximum flux density, A_C = Area of cross-section

$$400 = 4.44 \times B_m \times 90 \times 10^{-4} \times 50 \times 200$$

$$B_m = \frac{400 \times 10^4}{4.44 \times 10000 \times 90} = 1.001\ \text{Wb/m}^2 \approx 1\ \text{T}$$

59. **(b)**

We know,

Eddy current loss, $P_e = K_e f^2 B_m^2$

$$\frac{P_{e60}}{P_{e50}} = \left(\frac{f_{60}}{f_{50}}\right)^2 \left(\frac{B_{m60}}{B_{m50}}\right)^2$$

$$= \left(\frac{60}{50}\right)^2 \left(\frac{B_{m60}}{B_{m50}}\right)^2 \qquad \text{...(ii)}$$

We also know for given transformer,

$$\frac{V_{50}}{V_{60}} = \frac{f_{50} B_{m50}}{f_{60} B_{m60}} \qquad \text{as voltage are same}$$

$$1 = \frac{50\ B_{m50}}{60\ B_{m60}}$$

$$\therefore \qquad B_{m\,60} = \frac{5}{6} B_{m50} \qquad \text{...(ii)}$$

Using equation (i) and (ii),

$$P_{e\,60} = P_{e50}\left(\frac{60}{50}\right)^2 \left(\frac{5}{6}\right)^2 = P_{e\,50}$$

Alternate Solution:

$$P_e = K_e f^2 B_m^2$$

$$= K_e f^2 \frac{V^2}{f^2}$$

$$P_e = V^2$$

as voltages are same,

So, $P_{e60} = P_{e50}$

60. **(b)**

Both given statements are correct and are not related to each other.

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

61. (d)

$$B = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$$

$$AB = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix}\begin{bmatrix} 1 \\ -1 \end{bmatrix} = \begin{bmatrix} -1 \\ 1 \end{bmatrix}$$

$$|Q_C| = \left|\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}\right| = 0$$

Hence system is not controllable

Observability:

$$C = \begin{bmatrix} 1 & 1 \end{bmatrix}$$

$$CA = \begin{bmatrix} -1 & -1 \end{bmatrix}$$

$$|Q_0| = \left|\begin{bmatrix} 1 & 1 \\ -1 & -1 \end{bmatrix}\right| = 0$$

Hence system is not observable.

62. (d)

State variables describe only the past behavior of the system.

63. (a)

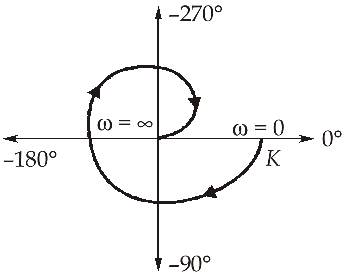
- Lead compensator improves the speed i.e. transient response.
- It also improves the bandwidth and stability is also improved.

Both the statements are correct.

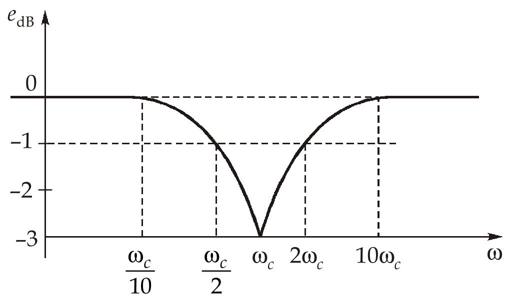
64. (b)

The system is type zero and order 4

ω	0	∞
M	K	0
ϕ	0°	–360°



65. (d)



From the above graph, the error in Bode plot at one decade above the corner frequency is zero dB.

66. (a)

Here,
$$A = 1,$$
$$B = 2,$$
$$C = 1$$
$$B^2 - 4AC = 4 - 4 = 0$$

Hence, it is a parabolic equation.

67. (b)

$$\frac{d^3y}{dx^3} - 7\frac{d^2y}{dx^2} + 10\frac{dy}{dx} = 0$$

$\Rightarrow$ $$D^3y - 7D^2y + 10Dy = 0$$

Auxiliary equation,

$\Rightarrow$ $$m^3 - 7m^2 + 10\,m = 0$$
$$m = 0, 2, 5$$

$\therefore$Solution
$$y = C_1e^{0x} + C_2e^{2x} + C_3e^{5x}$$
$$= C_1 + C_2e^{2x} + C_3e^{5x}$$

68. (a)

$f(z) = \frac{\cos z}{z}$ has a simple pole at $z = 0$ and $z = 0$ is inside unit circle on complex plane

$\therefore$ Residue of $f(z)$ at $z = 0$

$$\lim_{z\to 0} f(z)\cdot z = \lim_{z\to 0} \cos z = 1$$

$$\int_c f(z)dz = 2\pi i \times 1 = 2\pi i$$

69. **(c)**

Given,

$$\left(\frac{d^3y}{dx^3}\right)^{2/3}+\left(\frac{d^3y}{dx^3}\right)^{3/2} = 0$$

$$1+\left(\frac{d^3y}{dx^3}\right)^{\frac{3}{2}-\frac{2}{3}} = 0$$

$$\left(\frac{d^3y}{dx^3}\right)^{\frac{5}{6}} = -1$$

Raising power 6 on both sides

$$\left(\frac{d^3y}{dx^3}\right)^{5} = 1$$

From here degree of equation is 5.

70. **(c)**

A : The number 5 appears at least once.

B : The sum of the numbers appearing is 8.

The set of elementary events are therefore

$$A = \{(5, 1), (5, 2), (5,3), (5, 4)\ (5, 5), (5, 6), (1, 5), (2, 5), (3, 5), (4, 5), (6, 5)\}$$

$$B = \{(2, 6), (3, 5), (4, 4), (5, 3), (6, 2)\}$$

and $A \cap B = \{(5, 3), (3, 5)\}$

The total outcomes of throwing two dice is 6 × 6 = 36

Hence, $P(A) = \frac{11}{36}$,

$$P(B) = \frac{5}{36},$$

$$P(A \cap B) = \frac{2}{36}$$

$$P\left(\frac{A}{B}\right) = \frac{P(A\cap B)}{P(B)} = \frac{\frac{2}{36}}{\frac{5}{36}} = \frac{2}{5}$$

71. **(c)**

Probability of the ace of spades,

$$P = \frac{1}{52}$$

$$n = 104$$

$$m = np = 104 \times \frac{1}{52} = 2$$

$$P(r) = e^{-m} \cdot \frac{m^r}{r!} = e^{-2} \cdot \frac{2^r}{r!} = \frac{1}{e^2}\frac{2^r}{r!}$$

$$P(\text{at least once}) = P(1) + P(2) + P(3) + \ldots .\ P(104)$$

$$= 1 - P(0)$$

$$= 1 - \frac{1}{e^2} \times \frac{2^0}{0!} = 1 - e^{-2}$$

72. (b)

$$\arg(Z_1) = \theta_1 = \tan^{-1}\left(\frac{5\sqrt{3}}{5}\right)$$

$$\Rightarrow \quad \theta_1 = 60°$$

$$\arg(Z_2) = \theta_2 = \tan^{-1}\left(\frac{2\sqrt{3}}{6}\right)$$

$$\Rightarrow \quad \theta_2 = 30°$$

$$\arg\left(\frac{Z_1}{Z_2}\right) = \arg(Z_1) - \arg(Z_2)$$

$$= 60° - 30° = 30°$$

Hence, option (b) is correct.

73. (a)

Both the statements are correct and statement-II is correct explanation of statement-I.

74. (c)

If system matrix $A = I$, then the system is uncontrollable and unobservable.

75. (d)

Gain margin alone is inadequate to indicate relative stability when system parameters other than the loop gain are subject to variation. Due to variation in some parameters, phase shift of the system can vary which may result to instability. Hence, we must also consider the concept of phase margin for determining the relative stability of the system.

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