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Open Practice Test Series
(Also useful for ESE & Other Exams)

EE : ELECTRICAL ENGINEERING
TEST No. - 04 | POWER SYSTEMS

Read the following instructions carefully

1. This question paper contains 33 MCQ's & NAQ's. Bifurcation of the questions are given below:

Subjectwise Test Pattern

Questions	Question Type	No. of Questions	Marks	Total Marks	Negative Marking
1 to 9	Multiple Choice Ques.	9	1	9	0.33
10 to 16	Numerical Answer Type Ques.	7	1	7	None
17 to 25	Multiple Choice Ques.	9	2	18	0.66
26 to 33	Numerical Answer Type Ques.	8	2	16	None
Total Questions : 33		**Total Marks : 50**		**Total Duration : 90 min**	

2. Choose the closest numerical answer among the choices given.

Multiple Choice Questions : Q.1 to Q.9 carry 1 mark each

Q.1 A generating station has a connected load of 43 MW and a maximum demand of 20 MW, the units generated being 61.5×10^6 per annum. The laod factor is

(a) 0.35
(b) 0.75
(c) 0.25
(d) 0.56

1. (a)

$$\text{Average demand} = \frac{\text{Units generated/annum}}{\text{Hours in a year}}$$

$$= \frac{61.5 \times 10^6}{24 \times 365} = 7020.54 \text{ kW}$$

$$\text{Load factor} = \frac{\text{Average demand}}{\text{Maximum demand}} = \frac{7020.54 \text{ kW}}{20 \times 10^3 \text{ kW}}$$

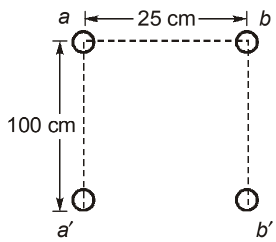
$$\text{Load factor} = 0.35$$

Q.2 Two conductors of a single phase line, each of 1 cm diameter and arranged in a vertical plane with one conductor mounted 1 m above the other. A second identical line is mounted at same height as the first and spaced horizontally 0.25 m apart from it. The two upper and the two lower conductors are connected in parallel. The loop inductance of the line is

(a) 0.42 mH/km
(b) 0.52 mH/km
(c) 0.71 mH/km
(d) 0.84 mH/km

2. (d)

Self GMD,



$$D_s = \sqrt[4]{(D_{aa}.D_{aa'}.D_{a'a'}.D_{a'a})}$$

$$= \sqrt[4]{(0.7788 \times 0.5)^2 (100)^2}$$

$$= 6.24 \text{ cm}$$

Mutual GMD between a and b is

$$D_{ab'} = D_{a'b}$$

$$= \sqrt{25^2 + 100^2} = 103.07 \text{ cm}$$

$$D_m = \sqrt[4]{(D_{ab}.D_{ab'}.D_{a'b}.D_{a'b'})}$$

$$= \sqrt[4]{25^2 \times (103.07)^2} = 50.76 \text{ cm}$$

$$\text{Inductance} = 2 \times 10^{-7} \, ln \frac{D_m}{D_s}$$

$$= 2 \times 10^{-7} \, ln \frac{50.76}{6.24} \text{ H/m}$$

$$= 0.42 \, \mu\text{H/m}$$

$$\text{Loop inductance} = 2 \times 0.42 \, \mu\text{H/m}$$

$$= 0.84 \text{ mH/km}$$

Q.3 A transmission line has $A = D = 0.8$, $B = 200\angle 90°\ \Omega$, $C = 0.5 \times 10^{-6}\ S$ and sending end voltage is 400 kV at no load. The sending end current in the line is

(a) 0.121 A (b) 0.1443 A
(c) 0.324 A (d) 0.414 A

3. (b)

No load receiving end voltage,

$$V_R = \frac{V_s}{A}$$

$$V_R = \frac{400}{0.8} = 500 \text{ kV}$$

$$\text{The sending end current} = I_s = CV_R$$

$$= (0.5 \times 10^{-6})\left(\frac{500 \text{ kV}}{\sqrt{3}}\right) = 0.1443 \text{ A}$$

Q.4 The symmetrical components are used in the fault analysis because

(a) The number of equations become smaller
(b) The sequence of networks do not have mutual couplings
(c) The results are required in terms of symmetrical components
(d) None of above

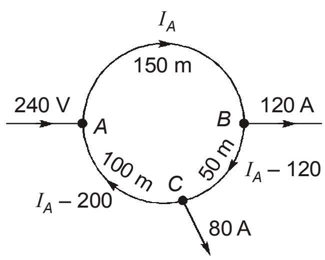
4. (b)

Q.5 A 2 wire *dc* ring distributor is 300 m long and is fed at 240 V at point A. At point B, 150 m from A, a load of 120 A is taken and at *C*, 100 m in the opposite direction, a load of 80 A is taken. If resistance per 100 m of single conductor is 0.03 Ω, then the current in the section *AB* of feeder is

(a) 41.2 A (b) 102.4 A
(c) 52.3 A (d) 86.67 A

5. (d)

Resistance per 100 m of distributor = 2 × 0.03 = 0.06 Ω



Resistance of *AB*, $R_{AB} = (0.06)\left(\frac{150}{100}\right) = 0.09\ \Omega$

$$R_{BC} = 0.06 \times \frac{50}{100} = 0.03\Omega$$

$$R_{CA} = 0.06 \times \frac{100}{100} = 0.06\Omega$$

Applying KVL in the loop:

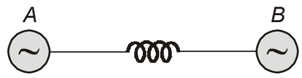
$$I_{AB} R_{AB} + I_{BC} R_{BC} + I_{CA} R_{CA} = 0$$

$$0.09\, I_{AB} + 0.03\, (I_{AB} - 120) + 0.06\, (I_{AB} - 200) = 0$$

$$0.18\, I_{AB} = 15.6$$

$$I_{AB} = \frac{15.6}{0.18} = 86.67 \text{ A}$$

Q.6 Two identical synchronous machine A and B running at same speed are linked through inductor as shown.



Machine A will supply active and reactive power to machine B when δ is

(a) Positive and $V_A < V_B$
(b) negative and $V_A > V_B$
(c) negative and $V_A < V_B$
(d) positive and $V_A > V_B$

6. (d)

Reactive power flow depends mainly on difference between voltage magnitudes and it flows from higher voltage to lower voltage.

Active power flow flows from leading angle bus to lagging angle bus.

Q.7 A 3-ϕ alternator can supply a maximum load of 5000 kVA at 6600 V. The machine has internal reactance of 6%. The reactance per phase of the limiting reactor if the steady apparent power (kVA) on short-circuit do not to exceed 5 times full load value is

(a) 1.22 Ω
(b) 4.12 Ω
(c) 2.13 Ω
(d) 3.21 Ω

7. (a)

Let base KVA be 5000 kVA

The SC kVA is not to exceed = 5 × 5000 kVA

$$\text{Fault kVA} = \text{Base kVA} \times \frac{100}{\%\text{ Reactance}}$$

$$5 \times 5000 = (5000)\left(\frac{100}{X+6}\right)$$

$$X = 14\%$$

$$X = \%\ X \times X_{base}$$

$$\text{ohmic value of } X = \frac{14}{100} \times \frac{(6.6 \times 10^3)^2}{5000 \times 10^3} = 1.22\ \Omega$$

Q.8 A transmission line has an impedance of $(2 + j8)\ \Omega$ has a voltage regulation of 10% with a lagging load of 0.8. If the load is 0.707 leading then the regulation is,

(Assume current is same in both cases.)

(a) –2.41%
(b) –1.2%
(c) –6.63%
(d) –4.21%

8. (c)

$$\text{Voltage regulation} = IR\cos\phi_R + IX\sin\phi_R$$

R = resistance

X = reactance

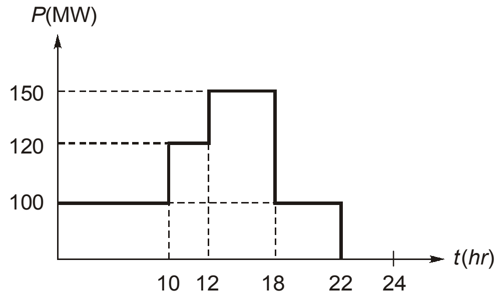
ϕ_R = receiving end angle between receiving end voltage and current (for lagging load it should be positive)

$$\frac{VR_1}{VR_2} = \frac{R\cos\phi_{R1} + X\sin\phi_{R1}}{R\cos\phi_{R2} - X\sin\phi_{R2}}$$

$$\frac{0.1}{VR_2} = \frac{2(0.8)+8(0.6)}{2(0.707)-8(0.707)}$$

$$VR_2 = -6.63\%$$

Q.9 A generating station has plant capacity of 200 MW. The power delivered by the generating station for 24 hours of duration is given by the following load curve.



The load factor is,

(a) 0.8
(b) 0.64
(c) 0.95
(d) 0.70

9. **(d)**

$$\text{Average load} = \frac{(100 \times 10) + (120 \times 2) + (150 \times 6) + (4 \times 100)}{24}$$

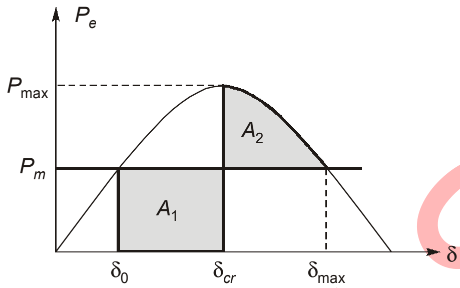
$$= 105.83 \text{ MW}$$

$$\text{Load factor} = \frac{\text{Average load}}{\text{Maximum demand}} = \frac{105.83}{150} = 0.7055$$

Numerical Answer Type Questions : Q. 10 to Q. 16 carry 1 mark each

Q.10 A generator delivers power of 1 pu to an infinite bus through a purely reactive network. The maximum power that could be delivered by generator is 2 pu. A 3-ϕ fault occurs at the terminals of the generator which reduces the generator output to zero. The fault is cleared after t_c second. The original network is then restored. The maximum swing of rotor angle is found to be δ_{max} = 110 electrical degrees. The rotor angle at $t = t_c$ is ________ electrical degrees.

10. 69.14 (68.70 to 69.30)



Power generated by generator

$$P_e = P_{max} \sin\delta$$

At δ_0,

$$P_e = 1 \text{ p.u.}$$

$$P_{max} = 2 \text{ p.u.}$$

$$\delta_{cr} = \text{rotor angle at } t = t_c$$

$$1 = 2\sin\delta_0$$

$$\delta_0 = \sin^{-1}\left(\frac{1}{2}\right) = 30^\circ$$

$$A_1 = A_2 = \text{equal area criterion}$$

$$\int_{\delta_0}^{\delta_{cr}} (P_m - 0)\,d\delta = \int_{\delta_{cr}}^{\delta_{max}} (P_{max}\sin\delta - P_m)\,d\delta$$

$$P_m(\delta_{cr} - \delta_0) = P_{max}(\cos\delta_{cr} - \cos\delta_{max}) - P_m(\delta_{max} - \delta_{cr})$$

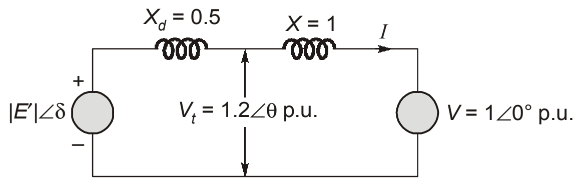
$$\cos\delta_{cr} = \frac{P_m}{P_{max}}(\delta_{max} - \delta_0) + \cos\delta_{max}$$

$$\cos\delta_{cr} = \frac{1}{2}\left[(110 - 30)\frac{\pi}{180}\right] + \cos 110^\circ$$

$$\delta_{cr} = 69.14^\circ$$

Q.11 A system consisting of a generator with equivalent reactance of 0.5 p.u. connected to an infinite bus through a series reactance of 1 p.u. The terminal voltage of generator is held at 1.2 p.u. and voltage of infinite bus is 1 p.u. The steady state power limit of the system is ________ p.u.

11. 1.15 (0.90 to 1.30)



$$V = 1\angle 0° \text{ p.u.}$$

$$V_t = 1.2\angle\theta \text{ p.u.}$$

$$I = \frac{V_t - V}{jX} = \frac{1.2\angle\theta - 1\angle 0°}{j1}$$

$$E = V_t + jX_d I = 1.2\angle\theta + j0.5\left[\frac{1.2\angle\theta - 1\angle 0°}{j1}\right]$$

$$E = 1.8\angle\theta - 0.5 = (1.8\cos\theta - 0.5) + j\,1.8\sin\theta$$

Steady state power limit is reached when E has $\delta = 90°$

i.e. real part is zero

$$1.8\cos\theta - 0.5 = 0$$

$$\theta = 73.87°$$

$$E = 1.8\angle 73.87° - 0.5$$

$$E = 1.729\angle 90° \text{ p.u.}$$

$$P_{\text{max}} = \frac{|E||V|}{X_d + X} = \frac{1.729 \times 1}{1.5} = 1.152 \text{ p.u.}$$

Q.12 A transmission line operating at 11 kV is delivering 20 MW of power. If the line voltage is changed to 33 kV, then the power transfer capability is increased to _______ MW.

12. 180 (178 to 182)

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

$$\frac{P_1}{P_2} = \left(\frac{V_1}{V_2}\right)^2$$

$$\frac{20}{P_2} = \left(\frac{11}{33}\right)^2$$

$\therefore$ $P_2 = 180$ MW

Q.13 Given a single area with two generating units.

Unit	Rating (MW)	Speed drop R (per unit on unit base)
1	400	0.04
2	800	0.05

The units share a load of P_1 = 200 MW, P_2 = 500 MW. The units are operating in parallel to share a load of 700 MW at 50 Hz frequency. The load is increased by 130 MW with B = 0, The value of new frequency caused by steady state frequency deviation is ______ Hz.

13. 49.75 (49.40 to 49.90)

$$\Delta f = \frac{-\Delta P}{\frac{1}{R_1} + \frac{1}{R_2} + B}$$

On a common base of 1000 MVA

$$R_1 = (0.04)\left(\frac{1000}{400}\right) = 0.1$$

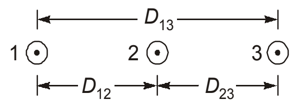
$$R_2 = (0.05)\left(\frac{1000}{800}\right) = 0.0625$$

$$\Delta f = \frac{-130/1000}{\frac{1}{0.1} + \frac{1}{0.0625}} = -5 \times 10^{-3} \text{ p.u.}$$

$$f = f_0 + \Delta f = 50 - (5 \times 10^{-3})(50)$$
$$= 49.75 \text{ Hz}$$

Q.14 In a 3-ϕ, 3 wire system, the conductors are arranged in a horizontal plane with spacing D_{13} = 4 m, $D_{12} = D_{23}$ = 2 m. Conductors are transposed having diameter of 2.5 cm. The ratio of mutual GMD to self GMD is ________ .

14. 258.83 (258.50 to 259.00)



$$\text{Mutual GMD} = \sqrt[3]{D_{12}.D_{23}.D_{13}} = \sqrt[3]{2 \times 2 \times 4} = 2.5198 \text{ m}$$

$$\text{Self GMD} = \left(0.7788 \times \frac{2.5}{2} \times 10^{-2}\right) = 9.735 \times 10^{-3} \text{ m}$$

$$\text{The ratio of mutual GMD to self GMD} = \left(\frac{2.5198}{9.735 \times 10^{-3}}\right) = 258.8392$$

Q.15 A 50 bus power system [Y_{bus}] has 80% sparsity. The total no. of transmission lines will be ________ .

15. 225 (220 to 230)

$$\text{No of no. zero elements} = 50 \times 50 \times \frac{20}{100} = 500 \text{ non-zero elements}$$

$$\text{No. of transmission line} = \frac{500 - 50}{2} = 225 \text{ transmission lines}$$

Q.16 A single core lead sheathed cable is graded by using three dielectrics of relative permittivity 5, 4, 3 respectively. The conductor diameter is 2 cm and overall diameter is 8 cm. If the 3 dielectrics works at the same maximum stress of 40 kV/cm, then the safe working rms voltage of cable is ________ kV.

16. 57.72 (57.50 to 57.90)

$$d = 2\text{ cm} \qquad d_1 = ?$$
$$d_2 = ? \qquad D = 8\text{ cm}$$
$$\epsilon_1 = 5 \qquad \epsilon_2 = 4$$
$$\epsilon_3 = 3 \qquad g_{max} = 40\text{ kV/cm}$$

As the maximum stress in the three dielectrics is same

$$\epsilon_1 d = \epsilon_2 d_1 = \epsilon_3 d_2$$
$$(5)(2) = 4d_1 = 3d_2$$
$$d_1 = 2.5\text{ cm}, \qquad d_2 = 3.33\text{ cm}$$

Permissible peak voltage for cable,

$$V_{max} = \frac{g_{max}}{2}\left[d\,ln\frac{d_1}{d} + d_1\,ln\frac{d_2}{d_1} + d_2\,ln\frac{D}{d_2}\right]$$
$$= \frac{40}{2}\left[2\,ln\frac{2.5}{2} + 2.5\,ln\frac{3.33}{2.5} + 3.33\,ln\frac{8}{3.33}\right] = 81.6326\text{ kV}$$

Safe working rms voltage of cable $= \dfrac{81.6326}{\sqrt{2}} = 57.72\text{ kV}$

Multiple Choice Questions : Q.17 to Q.25 carry 2 marks each

Q.17 A star connected, 3-ϕ , 10 MVA, 6.6 kV alternator is protected by Mery price circulating current principle using 1000/5 A CT. The star point of alternator is earthed through a resistance of 7.5 Ω. If the minimum operating current for relay is 0.5 A. Calculate % of each phase of stator winding that is unprotected against earth faults when machine is operating at normal voltage.

(a) 19.68 %
(b) 15.2 %
(c) 21.21 %
(d) 12.12 %

17. (a)

Let x% of the winding be unprotected

$$\text{Earthing resistance, } r = 7.5\ \Omega$$

$$\text{Voltage per phase, } V_{ph} = \frac{6.6\times10^3}{\sqrt{3}} = 3810\text{ V}$$

Minimum fault current which will operate the relay

$$= \frac{1000}{5}\times0.5 = 100\text{ A}$$

$$\text{emf induced in } x\%\text{ winding} = (V_{ph})\left(\frac{x}{100}\right) = (3810)\left(\frac{x}{100}\right) = 38.1\,x\text{ volts}$$

Earth fault current which x% considering will cause

$$= \frac{38.1x}{r} = \frac{38.1x}{7.5}\text{ A}$$

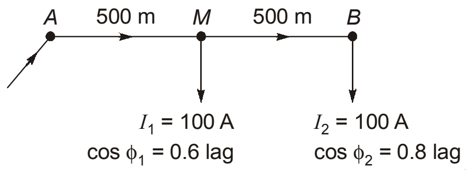
$$100 = \frac{38.1x}{7.5} = \text{given}$$

$$x = \frac{100\times7.5}{38.1} = 19.68\%$$

Q.18 A single phase distributer of 1 km long has resistance and reactance per conductor of 0.1 Ω and 0.15 Ω respectively. If the far end voltage V_B = 200 V and current is 100 A at 0.8 pf lag. At the midpoint *M* of the distributor, a current of 100 A is tapped at a pf of 0.6 lag with reference to the voltage V_m at mid point. The voltage magnitude at mid point is

(a) 230 V (b) 211 V
(c) 218 V (d) 222 V

18. (c)



Impedance of section AM and MB,

$$Z_{AM} = Z_{MB} = (0.1 + j\,0.15)\ \Omega$$

Load current at point *B*, $I_2 = 100\ \angle{-\cos^{-1}}(0.8) = 100\ \angle{-36.87°}$ A

Current in section MB $= 100\ \angle{-36.87°}$ A

Drop in section *MB*,
$$\vec{V}_{MB} = I_2 Z_{MB}$$
$$= (100\ \angle{-36.87°}\ \text{A})\ (0.1 + j0.15)$$
$$= 18.027\ \angle 19.44°\ \text{V}$$

Magnitude of voltage at point *M*,
$$V_M = 200 + 18.027$$
$$= 218.027\ \text{V}$$

Q.19 A generator of negligible resistance having 1.0 per unit voltage behind transient reactance is subjected to different types of faults.

Type of Fault	Resulting fault current in p.u.
3 - phase	3.33
L – L	2.23
L – G	3.01

The per unit values of X_1 and X_2 respectively are.

(a) 2.24 and 1.27 p.u. (b) 4.2 and 2.27 p.u.
(c) 3.3 and 0.47 p.u. (d) 1.27 and 1.24 p.u.

19. (c)

For three phase fault,

$$\text{Fault current, } I_f = \frac{E_a}{X_1} = \frac{1}{X_1} = 3.33\ \text{p.u.}$$

$$\therefore \quad X_1 = 0.3\ \text{p.u.}$$

for L-L fault,

$$\text{Fault current, } I_f = \frac{\sqrt{3}\,E_a}{X_1 + X_2} = 2.23$$

$$\frac{\sqrt{3}}{2.23} = 0.3 + X_2$$

$$X_2 = 0.4767\ \text{p.u.}$$

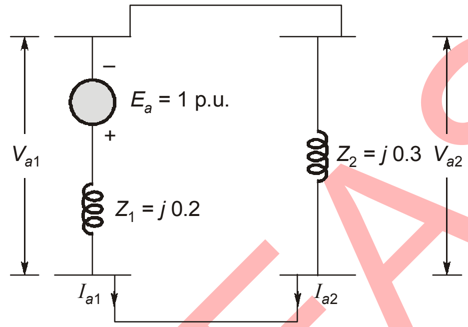
Q.20 A 25 MVA, 11 kV generator has $X_d'' = 0.2$ p.u. Its negative and zero sequence reactances are respectively 0.3 and 0.1 p.u. The neutral of generator is solidly grounded. If the fault occured in line to line on *b* and *c* phases, then line to line voltage V_{ab} is

(a) 11.43 kV (b) 10.10 kV
(c) 12.41 kV (d) 9-8 kV

20. (a)

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix} \begin{bmatrix} V_{a1} \\ V_{a2} \\ V_{a0} \end{bmatrix}$$

Sequence network representing L-L fault on phases *b* and *c*,



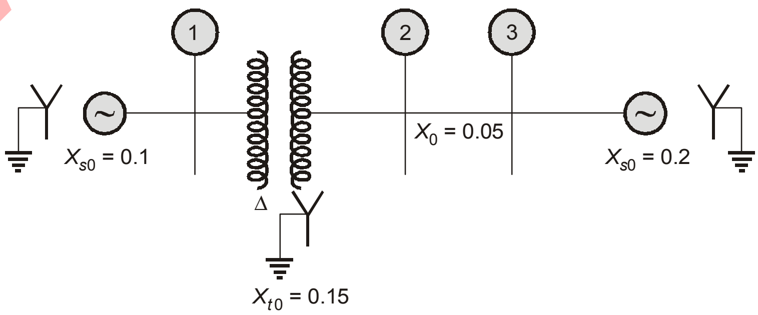
$$I_{a1} = -I_{a2} = \frac{1}{j0.5} = -j\,2 \text{ p.u.}$$

from the above network

$$V_{a1} = V_{a2}$$
$$V_{a1} = E_a - I_{a1} X_1$$
$$= 1 - (-j2)(j\,0.2) = 0.6 \text{ p.u.}$$

$\therefore$
$$V_{a1} = V_{a2} = 0.6 \text{ p.u.}$$
$$V_{ab} = V_a - V_b$$
$$= (V_{a1} + V_{a2} + V_{a0}) - (\alpha^2 V_{a1} + \alpha V_{a2} + V_{a0})$$
$$= 2V_{a1} - (\alpha^2 + \alpha) V_{a1} = (2 - \alpha^2 - \alpha)\, 0.6$$
$$V_{ab\,\text{p.u.}} = 1.8 \text{ p.u.}$$
$$V_{ab} = 1.8 \times \frac{11}{\sqrt{3}} = 11.43 \text{ kV}$$

Q.21 The zero sequence reactance (in p.u.) are indicated in the network shown below,

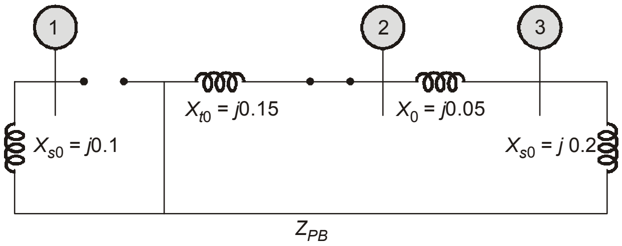


The zero sequence driving point reactance of node 3 will be

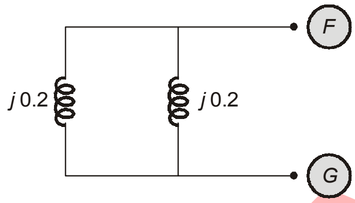
(a) 0.10 (b) 0.05
(c) 0.20 (d) 0.25

21. (a)

Let a fault occurs at node 3 then, the zero sequence network will be as shown below (using switch diagram for transformer)



the above network can be reduced by

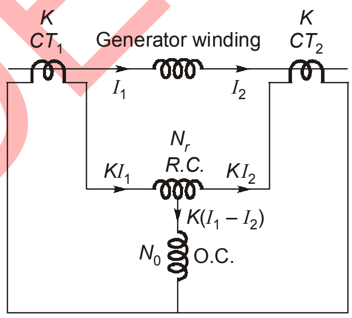


$$Z_{03} = \frac{j0.2 \times j0.2}{j0.2 \times j0.2} = j0.1 = 0.10 \text{ p.u.}$$

Q.22 In a biased differential relay the bias is defined as a ratio of

(a) number of turns of restraining and operating coils.
(b) operating coil current and restraining coil current.
(c) fault current and operating coil current.
(d) fault current and restraining coil current.

22. (a)



Percentage differential scheme for generator winding is shown above. Relay trips if flux

$$\phi_{O.C.} > \phi_{R.C.}$$

i.e. $$(mmf)_{O.C.} > (mmf)_{R.C.}$$

or, $$N_0\ K(I_1 - I_2) > \frac{N_r}{2} KI_1 + \frac{N_r}{2} KI_2$$

or, $$(I_1 - I_2) > \frac{N_r}{N_0}\left(\frac{I_1 + I_2}{2}\right)$$

If $$\frac{N_r}{N_0} = 0.05, \text{ then}$$

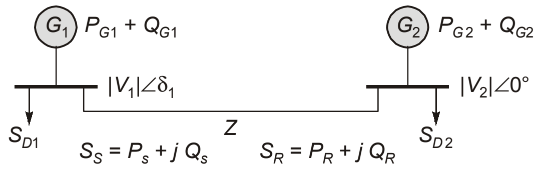
$$(I_1 - I_2) > 0.05\left(\frac{I_1 + I_2}{2}\right)$$

Relay trips if difference is more than 5% of average value of current. So, % bias is given by $\frac{N_r}{N_0}$.

Q.23 An interconnector cable links generating station 1 and 2 as shown below. The desired voltage profile is flat $|V_1| = |V_2| = 1\,\text{p.u.}$. Total demand at bus 1 and 2 are:

$$S_{D1} = 15 + j\,5 \text{ p.u.}$$
$$S_{D2} = 25 + j\,15 \text{ p.u.}$$

Cable has $\quad Z = j\,0.05$ p.u.



The torque angle δ is

(a) 10.4° (b) 14.5°
(c) 20.1° (d) 17.2°

23. (a)

Since cable resistance in zero, there is no real power loss in the cable. Hence

$$P_{G1} = P_{G2} = P_{D1} + P_{D2} = 40 \text{ p.u.}$$

For equalization of station loads

$$P_{G1} = P_{G2} = 20 \text{ p.u.}$$

Voltage of bus 2 is taken as reference i.e. $V_2\angle 0°$ and voltage of bus 1 is $V_1\angle\delta_1$. Further for flat voltage profile

$$|V_1| = |V_2| = 1$$

Real power flow from bus 1 to bus 2

$$R = 0, \qquad \theta = 90°$$

$$P_s = P_R = \frac{|V_1|\,|V_2|}{X}\sin\delta_1$$

$$5 = \frac{1\times 1}{0.05}\sin\delta_1$$

$$\delta_1 = 14.4°$$

Q.24 A 3-phase transmission line is supported by a 3 unit suspension insulator stirng. The voltage across the unit nearest to the line is 20 kV and that across the adjacent unit is 15 kV. The ratio of mutual to ground capacitance is

(a) 0.12 (b) 0.14
(c) 0.16 (d) 0.18

24. (d)

number of units = 3

Voltage across the second unit, V_2 = 15 kV

Voltage across the thrid unit, V_3 = 20 kV

$$\frac{V_3}{V_2} = \frac{V_1(1+3K+K^2)}{V_1(1+K)}$$

$$\frac{20}{15} = \frac{1+3K+K^2}{1+K}$$

$$20\,K + 20 = 15 + 45\,K + 15\,K^2$$

$$15\,K^2 + 25\,K - 5 = 0$$

$$K = 0.18 \text{ by ignoring the negative value.}$$

Q.25 A power station has a maximum demand of 15000 kW. Annual load factor is 50% and plant capacity factor is 40%. The reserve capacity of the plant is
(a) 3750 kW
(b) 5000 MW
(c) 1241 kW
(d) 4800 MW

25. (a)

$$\text{Load factor} = \frac{\text{Average load}}{\text{Maximum demand}} = 0.5$$

$$\text{Plant capacity factor} = \frac{\text{Average load}}{\text{Plant capacity}} = 0.4$$

$$\frac{\dfrac{\text{Average load}}{\text{Maximum demand}}}{\dfrac{\text{Average load}}{\text{Plant capacity}}} = \frac{0.5}{0.4}$$

$$\text{Plant capacity} = \frac{0.5}{0.4} \times \text{maximum demand}$$

$$= \frac{0.5}{0.4} \times 15000$$

$$\text{Plant capacity} = 18750 \text{ kW}$$

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

$$= 18750 - 15000 = 3750 \text{ kW.}$$

Numerical Answer Type Questions : Q. 26 to Q. 33 carry 2 marks each

Q.26 Three plants of a total capacity of 500 MW are scheduled for operation to supply a total system load of 310 MW.

$$C_1 = 0.06P_{G1}^2 + 30P_{G1} + 10, \qquad 30 \le P_{G1} \le 150$$

$$C_2 = 0.10P_{G2}^2 + 40P_{G1} + 15, \qquad 20 \le P_{G2} \le 100$$

$$C_3 = 0.075P_{G3}^2 + 10P_{G3} + 20, \qquad 50 \le P_{G3} \le 250$$

The generation of plant 1 if optimal scheduling is done is ______ MW.

26. 87.03 (86.80 to 87.40)

The incremental fuel costs of three plants are:

$$\frac{dC_1}{dP_{G1}} = 0.12\,P_{G1} + 30$$

$$\frac{dC_2}{dP_{G2}} = 0.20\,P_{G2} + 40$$

$$\frac{dC_3}{dP_{G3}} = 0.15\,P_{G3} + 10$$

$$P_{G1} + P_{G2} + P_{G3} = 310\text{ MW}$$

$$\frac{dC_1}{dP_{G1}} = \frac{dC_2}{dP_{G2}} = \frac{dC_3}{dP_{G3}}$$

$$0.12\,P_{G1} + 30 = 0.20\,P_{G2} + 40$$

$$0.12\,P_{G1} + 30 = 0.15\,P_{G3} + 10$$

Solving the above equations we get,

$$P_{G1} = 94.44\text{ MW}$$

$$P_{G2} = 6.66\text{ MW}$$

$$P_{G3} = 208.88\text{ MW}$$

It is observed that real power generation of unit 2 is 6.66 MW and limit is violated. Hence we have to fix its value at its minimum generation.

$$P_{G2} = 20\text{ MW}$$

Given,

$$P_{G1} + P_{G2} + P_{G3} = 310\text{ MW}$$

$$P_{G1} + P_{G3} = 310 - 20 = 290\text{ MW}$$

The remaining load of 290 MW is to be distributed optimally between unit 1 and unit 3

$$\frac{dC_2}{dP_{G1}} = \frac{dC_3}{dP_{G3}}$$

$$0.12\,P_{G1} + 30 = 0.15\,P_{G3} + 10$$

Solving above equation,

We get,

$$P_{G1} = 87.03\text{ MW}$$

$$P_{G2} = 20\text{ MW}$$

$$P_{G3} = 202.96\text{ MW}$$

Q.27 A 100 MVA synchronous generator operates on full load at a frequency of 50 Hz. The load is suddenly reduced to 50 MW. Due to time lag in governor system, the steam valve begins to close after 0.4 seconds. The change in frequency that occurs in this time is ________ Hz. (H = 5 kW–s /KVA of generator capacity)

27. 1 (0.90 to 1.10)

The rating of the machine,

$$G = 100 \text{ MVA}$$

$$\text{Inertia constant} = H = 5 \text{ kW–s /KVA} = 5 \text{ MJ/MVA}$$

Kinetic energy stored in the rating parts of the generator and turbine at synchronous speed (f = 50 Hz)

$$= HG = 5 \times 100 = 500 \text{ MJ.}$$

Energy transferred in 0.4 sec $= 50 \times 0.4 = 20$ MJ

$KE \propto \text{speed}^2 \propto f^2$

$$\frac{KE_1}{KE_2} = \frac{(f_1)^2}{(f_2)^2}$$

$$\frac{500}{500+20} = \frac{(50)^2}{f_2^2}$$

$$f_2 = \sqrt{(50)^2 \frac{(500+20)}{500}} = 50 \times \sqrt{\frac{520}{500}}$$

$$f_2 = 50 \times 1.02 = 51 \text{ Hz}$$

$\therefore$ Change in frequency $= f_2 - f_1 = 1$ Hz

Q.28 A single phase motor is connected to 400 V, 50 Hz supply. The motor draws a current of 31.7 A at a power factor of 0.7 lag. The capacitance required in parallel with motor to raise the power factor to 0.9 lag is ____________ μF.

28. 94.62 (94.40 to 94.80)

Active power drawn by the motor

$$= VI\cos\theta_1$$

$$= 400 \times 31.7 \times 0.7$$

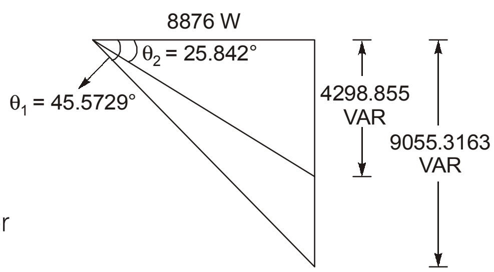
$$= 8876 \text{ W}$$

$$\text{Reactive power} = VI\sin\theta_1 = 400 \times 31.7 \times \sin(45.5729°)$$

$$= 9055.3163 \text{ VAR.}$$

$$\text{New power factor} = \cos\theta_2 = 0.9$$

$$\theta_2 = \cos^{-1}(0.9) = 25.842°$$



Reactive power after compensation $= Q_2$

$$Q_2 = 8876 \times \tan(25.842°)$$

$$= 4298.855 \text{ VAR}$$

$\therefore$ Reactive power that must be compensated by capacitor

$$Q_C = 9055.3163 - 4298.855$$

$$= 4756.4613 \text{ VAR}$$

$$Q_C = \frac{V^2}{X_C} = V^2 2\pi f C$$

$$\frac{4756.4613}{400^2 \times 2\pi \times 50} = C$$

$$C = 94.62 \,\mu\text{F}$$

Q.29 A 275 kV transmission line has following line constants,

$$A = 0.85\angle 5°,\ B = 200\angle 75°\ \Omega$$

The active power that is received if voltage profile at each end is maintained at 275 kV is ______ MW.

29. 117.63 (117.40 to 117.80)

Given $|V_S| = |V_R| = 275$ kV,

$$\alpha = 5°,\ \beta = 75°$$

$Q_R = 0$ (Receiving end reactive power is zero as voltage profile at each end is constant)

$$0 = \frac{275\times 275}{200}\sin(75° - \delta) - \frac{0.85}{200}\times(275)^2\sin(75° - 5°)$$

$$0 = 378.125\sin(75° - \delta) - 302.023$$

$$\delta = 22°$$

Receiving end active power

$$P_R = \frac{275\times 275}{200}\cos(75° - 22°) - \frac{0.85}{200}\times(275)^2\cos 70°$$

$$= 117.63\text{ MW}$$

Q.30 A 50 Hz four pole turbo-generator rated 100 MVA, 11 kV has an inertia constant of 8 MJ/MVA. If the mechanical input is suddenly raised to 80 MW for an electrical load of 50 MW, then the rotor acceleration is ________ elec.deg/s^2

30. 337.5 (337.20 to 337.70)

Stored energy $= GH = 100\times 8 = 800$ MJ

Accelerating power $= P_a = 80 - 50 = 30$ MW

$$P_a = M\frac{d^2\delta}{dt^2}$$

$$M = \frac{GH}{180f} = \frac{800}{180\times 50} = \frac{4}{45}\text{ MJ-s/elec.deg}$$

$$\frac{4}{45}\frac{d^2\delta}{dt^2} = 30$$

rotor acceleration, $\alpha = \dfrac{d^2\delta}{dt^2} = 337.5$ elec deg/s^2

Q.31 A 3-phase 220 kV line consisting of 22.26 mm diameter conductors speed in a a 6 m delta configuration. The following data is taken: Temperature 25° C, pressure 73 cm of mercury and surface factor is 0.84. The critical disruptive line to line voltage is ________ KV. (Dielectric strength of air, 90 = 21.1 KV/cm (rms))

31. 206.31 (206.00 to 206.60)

$$\text{Conductor radius, } r = \frac{22.26}{2} = 11.13 \text{ mm (or) } 1.113 \text{ cm}$$

Spacing between the conductors = d = 6 m = 600 cm

Dielectric strength of air g_0 = 21.1 KV/cm (rms)

$$\text{Air density factor} = \delta = \frac{3.92b}{273+t} = \frac{3.92\times 73}{273+25} = 0.96$$

Critical disruptive voltage to neutral,

$$V_{d0} = g_0\,\delta m_0 r \log_e \frac{d}{r}$$

$$= 21.1\times 0.96\times 0.84\times 1.113\log_e\left(\frac{600}{1.113}\right)$$

$$= 119.116 \text{ KV/phase}$$

Critical disruptive line to line voltage

$$= \sqrt{3}\times 119.116$$

$$= 206.31 \text{ KV}$$

Q.32 A 1-phase transmission line having *Cu* conductor of 0.775 cm^2 cross-section, through which 200 kW at unity power factor and at 3300 V is to be delivered. If the η of transmission is 90%, then the minimum length of transmission line is ________ km. (take specific resistance as 1.725 $\mu\Omega$/cm)

32. 13.6 (13.30 to 13.80)

Receiving end power = 200 kW

Transmission η = 0.9

$$\text{Sending end power} = \frac{200000}{0.9} = 222222.22 \text{ W}$$

$$\text{Line losses} = 222222.22 - 200000 = 22222.22 \text{ W}$$

$$\text{line current, } I = \frac{200\times 10^3}{3300} = 60.60 \text{ A}$$

Let R be the resistance of one conductor

$$\text{line losses} = 2\,I^2\,R$$

$$22222.22 = 2\,(60.6)^2\,\text{R}$$

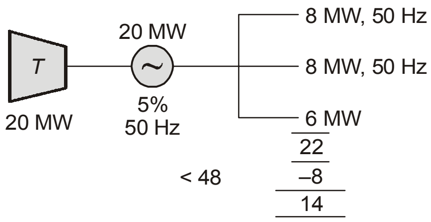
$$R = \frac{22222.22}{2(60.6)^2} = 3.025\,\Omega$$

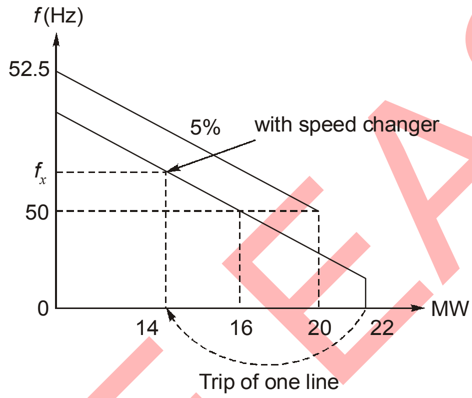
$$R = \frac{\rho l}{a}$$

$$l = \frac{3.025\times 0.775}{1.725\times 10^{-6}} = 1.36\times 10^6 \text{ cm} = 13.6 \text{ km}$$

Q.33 An isolated generator connected to a turbine with its continuous maximum power of 20 MW, 50 Hz. Generator connected with two loads of 8 MW, each operate at 50 Hz. Generator has 5% drop characteristic. One of these loads are programmed to trip if frequency full belows 48 Hz. If an additional load of 6 MW added then frequency of generator is ________ Hz.

33. **50.25 (50.10 to 50.30)**





From droop characteristic,

$$\frac{\Delta f_1}{\Delta P_1} = \frac{\Delta f_2}{\Delta P_2}$$

$$\frac{2.5}{20} = \frac{\Delta f_2}{2}$$

$$\Rightarrow \quad \Delta f_2 = 0.25$$

$$f_x = 50 + 0.25 = 50.25 \text{ Hz}$$

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