CHAPTER 5

POWER SYSTEMS

YEAR 2012 **ONE MARK**

MCQ 5.1 The bus admittance matrix of a three-bus three-line system is

$$Y = j\begin{bmatrix} -13 & 10 & 5 \\ 10 & -18 & 10 \\ 5 & 10 & -13 \end{bmatrix}$$

If each transmission line between the two buses is represented by an equivalent π-network, the magnitude of the shunt susceptance of the line connecting bus 1 and 2 is

(A) 4 (B) 2

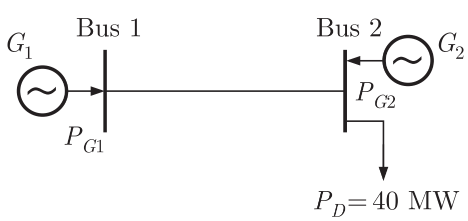
(C) 1 (D) 0

MCQ 5.2 A two-phase load draws the following phase currents : $i_1(t) = I_m \sin(\omega t - \phi_1)$, $i_2(t) = I_m \cos(\omega t - \phi_2)$. These currents are balanced if ϕ_1 is equal to.

(A) $-\phi_2$ (B) ϕ_2

(C) $(\pi/2 - \phi_2)$ (D) $(\pi/2 + \phi_2)$

MCQ 5.3 The figure shows a two-generator system applying a load of $P_D = 40$ MW, connected at bus 2.



The fuel cost of generators G_1 and G_2 are :
$C_1(P_{G1}) = 10000$ Rs/MWh and $C_2(P_{G2}) = 12500$ Rs/MWh and the loss in the line is $P_{loss(pu)} = 0.5P^2_{G1(pu)}$, where the loss coefficient is specified in pu on a 100 MVA base. The most economic power generation schedule in MW is

(A) $P_{G1} = 20, P_{G2} = 22$ (B) $P_{G1} = 22, P_{G2} = 20$

(C) $P_{G1} = 20, P_{G2} = 20$ (D) $P_{G1} = 0, P_{G2} = 40$

MCQ 5.4 The sequence components of the fault current are as follows : $I_{\text{positive}} = j1.5$ pu, $I_{\text{negative}} = -j0.5$ pu, $I_{\text{zero}} = -j1$ pu. The type of fault in the system is

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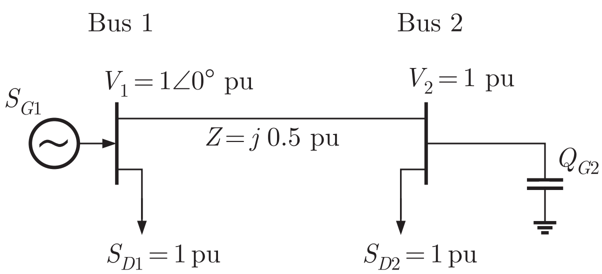
(A) LG (B) LL
(C) LLG (D) $LLLG$

YEAR 2012 TWO MARKS

MCQ 5.5 For the system below, $\boldsymbol{S}_{D1}$ and $\boldsymbol{S}_{D2}$ are complex power demands at bus 1 and bus 2 respectively. If $|\boldsymbol{V}_2| = 1$ pu, the VAR rating of the capacitor ($\boldsymbol{Q}_{G2}$) connected at bus 2 is



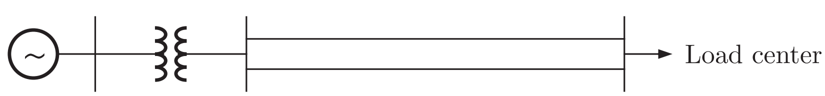
(A) 0.2 pu (B) 0.268 pu
(C) 0.312 pu (D) 0.4 pu

MCQ 5.6 A cylinder rotor generator delivers 0.5 pu power in the steady-state to an infinite bus through a transmission line of reactance 0.5 pu. The generator no-load voltage is 1.5 pu and the infinite bus voltage is 1 pu. The inertia constant of the generator is 5 MW-s/MVA and the generator reactance is 1 pu. The critical clearing angle, in degrees, for a three-phase dead short circuit fault at the generator terminal is

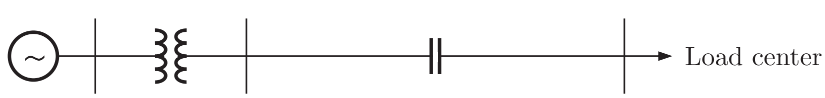
(A) 53.5 (B) 60.2
(C) 70.8 (D) 79.6

YEAR 2011 ONE MARK

MCQ 5.7 A nuclear power station of 500 MW capacity is located at 300 km away from a load center. Select the most suitable power evacuation transmission configuration among the following options

(A)


132 kV, 300 km double circuit

(B)


132 kV, 300 km single circuit with 40% series capacitor compensation

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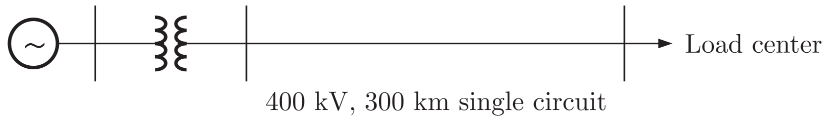
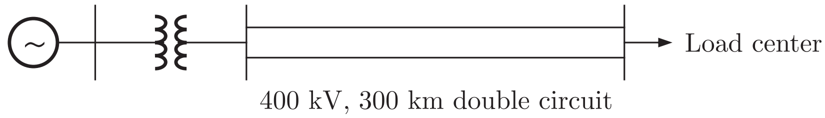
(C) 

(D) 

MCQ 5.8 A negative sequence relay is commonly used to protect

(A) an alternator (B) an transformer

(C) a transmission line (D) a bus bar

MCQ 5.9 For enhancing the power transmission in along EHV transmission line, the most preferred method is to connect a

(A) Series inductive compensator in the line

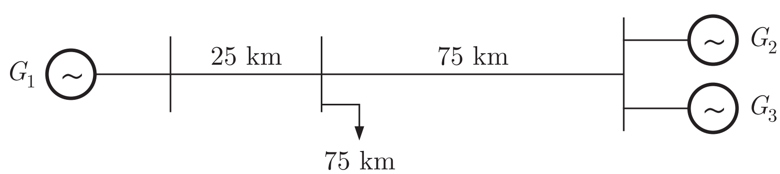
(B) Shunt inductive compensator at the receiving end

(C) Series capacitive compensator in the line

(D) Shunt capacitive compensator at the sending end

YEAR 2011 TWO MARKS

MCQ 5.10 A load center of 120 MW derives power from two power stations connected by 220 kV transmission lines of 25 km and 75 km as shown in the figure below. The three generators G_1, G_2 and G_3 are of 100 MW capacity each and have identical fuel cost characteristics. The minimum loss generation schedule for supplying the 120 MW load is



(A) $P_1 = 80$ MW + losses, $P_2 = 20$ MW, $P_3 = 20$ MW

(B) $P_1 = 60$ MW, $P_2 = 30$ MW + losses, $P_3 = 30$ MW

(C) $P_1 = 40$ MW, $P_2 = 40$ MW, $P_3 = 40$ MW + losses

(D) $P_1 = 30$ MW + losses, $P_2 = 45$ MW, $P_3 = 45$ MW

MCQ 5.11 The direct axis and quadrature axis reactances of a salient pole alternator are 1.2 p.u and 1.0 p.u respectively. The armature resistance is negligible. If this alternator is delivering rated kVA at upf and at rated voltage then its

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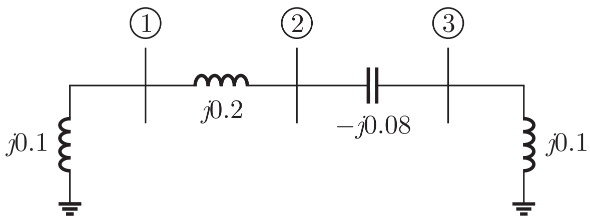
power angle is

(A) $30°$ (B) $45°$

(C) $60°$ (D) $90°$

MCQ 5.12 A three – bus network is shown in the figure below indicating the p.u. impedance of each element.



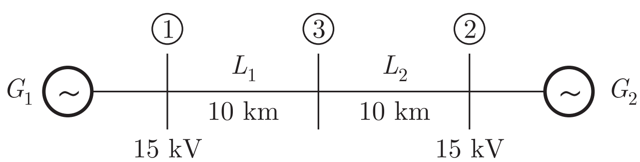
The bus admittance matrix, Y-bus, of the network is

(A) $j\begin{bmatrix} 0.3 & -0.2 & 0 \\ -0.2 & 0.12 & 0.08 \\ 0 & 0.08 & 0.02 \end{bmatrix}$ (B) $j\begin{bmatrix} -15 & 5 & 0 \\ 5 & 7.5 & -12.5 \\ 0 & -12.5 & 2.5 \end{bmatrix}$

(C) $j\begin{bmatrix} 0.1 & 0.2 & 0 \\ 0.2 & 0.12 & -0.08 \\ 0 & -0.08 & 0.10 \end{bmatrix}$ (D) $j\begin{bmatrix} -10 & 5 & 0 \\ 5 & 7.5 & 12.5 \\ 0 & 12.5 & -10 \end{bmatrix}$

Statement For Linked Answer Questions : 13 & 14.

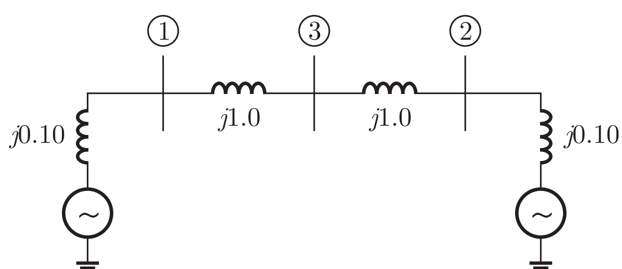
MCQ 5.13 Two generator units G_1 and G_2 are connected by 15 kV line with a bus at the mid-point as shown below



$G_1 = 250\,\text{MVA}$, 15 kV, positive sequence reactance $X_{G_1} = 25\%$ on its own base

$G_2 = 100\,\text{MVA}$, 15 kV, positive sequence reactance $X_{G_2} = 10\%$ on its own base L_1 and $L_2 = 10\,\text{km}$, positive sequence reactance $X_L = 0.225\,\Omega/\text{km}$

(A)



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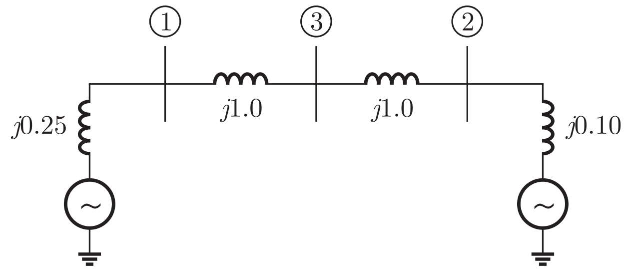
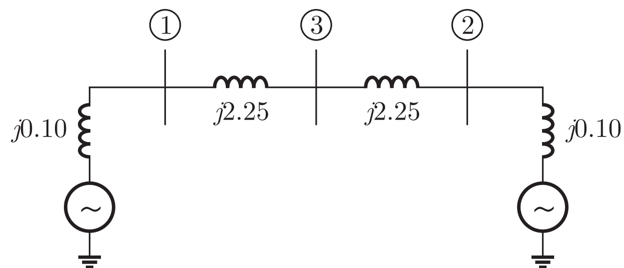
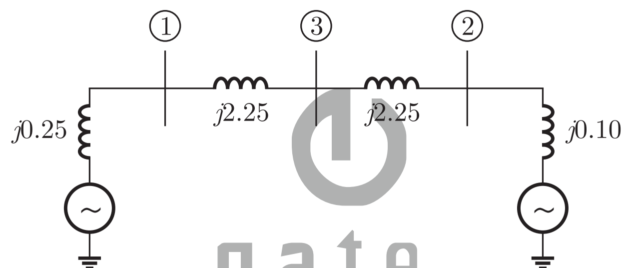
(B)



(C)



(D)



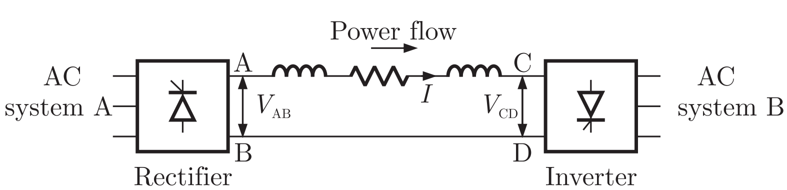
MCQ 5.14 In the above system, the three-phase fault MVA at the bus 3 is

(A) 82.55 MVA (B) 85.11 MVA

(C) 170.91 MVA (D) 181.82 MVA

YEAR 2010 ONE MARK

MCQ 5.15 Power is transferred from system A to system B by an HVDC link as shown in the figure. If the voltage V_{AB} and V_{CD} are as indicated in figure, and $I > 0$, then



(A) $V_{AB} < 0, V_{CD} < 0, V_{AB} > V_{CD}$

(B) $V_{AB} > 0, V_{CD} > 0, V_{AB} < V_{CD}$

(C) $V_{AB} > 0, V_{CD} > 0, V_{AB} > V_{CD}$

(D) $V_{AB} > 0, V_{CD} < 0$

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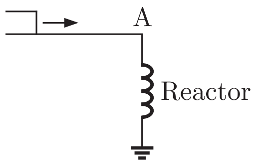
MCQ 5.16 Consider a step voltage of magnitude 1 pu travelling along a lossless transmission line that terminates in a reactor. The voltage magnitude across the reactor at the instant travelling wave reaches the reactor is



(A) -1 pu (B) 1 pu

(C) 2 pu (D) 3 pu

MCQ 5.17 Consider two buses connected by an impedence of $(0+5j)\,\Omega$. The bus '1' voltage is $100\angle 30^\circ$ V, and bus '2' voltage is $100\angle 0^\circ$ V. The real and reactive power supplied by bus '1' respectively are

(A) 1000 W, 268 VAr (B) -1000 W, -134 VAr

(C) 276.9 W, -56.7 VAr (D) -276.9 W, 56.7 VAr

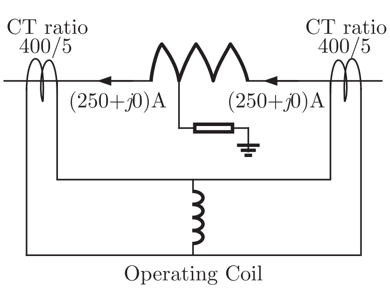
YEAR 2010 **TWO MARKS**

MCQ 5.18 A three-phase, 33 kV oil circuit breaker is rated 1200 A, 2000 MVA, 3 s. The symmetrical breaking current is

(A) 1200 A (B) 3600 A

(C) 35 kA (D) 104.8 kA

MCQ 5.19 Consider a stator winding of an alternator with an internal high-resistance ground fault. The currents under the fault condition are as shown in the figure The winding is protected using a differential current scheme with current transformers of ratio 400/5 A as shown. The current through the operating coils is



(A) 0.1875 A (B) 0.2 A

(C) 0.375 A (D) 60 kA

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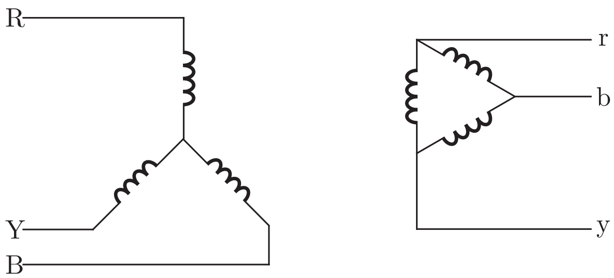
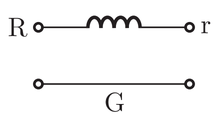
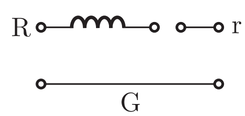
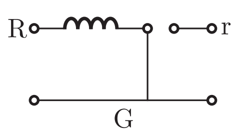
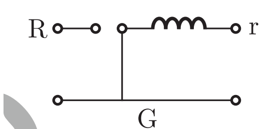
MCQ 5.20 The zero-sequence circuit of the three phase transformer shown in the figure is



(A) 

(B) 

(C) 

(D) 

MCQ 5.21 A 50 Hz synchronous generator is initially connected to a long lossless transmission line which is open circuited at the receiving end. With the field voltage held constant, the generator is disconnected from the transmission line. Which of the following may be said about the steady state terminal voltage and field current of the generator ?

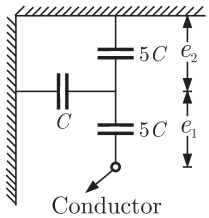
(A) The magnitude of terminal voltage decreases, and the field current does not change.

(B) The magnitude of terminal voltage increases, and the field current does not change.

(C) The magnitude of terminal voltage increases, and the field current increases

(D) The magnitude of terminal voltage does not change and the field current decreases.

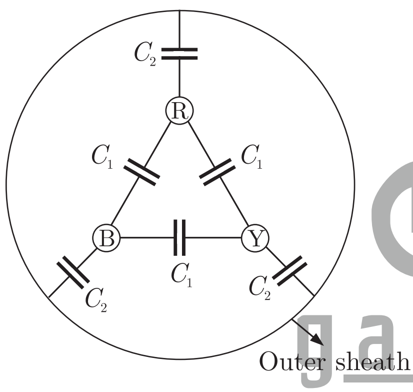
MCQ 5.22 Consider a three-phase, 50 Hz, 11 kV distribution system. Each of the conductors is suspended by an insulator string having two identical porcelain insulators. The self capacitance of the insulator is 5 times the shunt capacitance between the link and the ground, as shown in the figures. The voltages across the two insulators are



(A) $e_1 = 3.74\text{ kV}, e_2 = 2.61\text{ kV}$ (B) $e_1 = 3.46\text{ kV}, e_2 = 2.89\text{ kV}$

(C) $e_1 = 6.0\text{ kV}, e_2 = 4.23\text{ kV}$ (D) $e_1 = 5.5\text{ kV}, e_2 = 5.5\text{ kV}$

MCQ 5.23 Consider a three-core, three-phase, 50 Hz, 11 kV cable whose conductors are denoted as R, Y and B in the figure. The inter-phase capacitance(C_1) between each line conductor and the sheath is $0.4\,\mu\text{F}$. The per-phase charging current is



(A) 2.0 A (B) 2.4 A

(C) 2.7 A (D) 3.5 A

MCQ 5.24 For the power system shown in the figure below, the specifications of the components are the following :

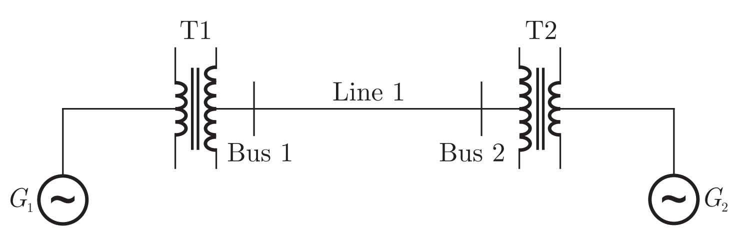
G_1: 25 kV, 100 MVA, $X = 9\%$

G_2: 25 kV, 100 MVA, $X = 9\%$

T_1: 25 kV/220 kV, 90 MVA, $X = 12\%$

T_2: 220 kV/25 kV, 90 MVA, $X = 12\%$

Line 1: 200 kV, $X = 150$ ohms



Choose 25 kV as the base voltage at the generator G_1, and 200 MVA as the MVA base. The impedance diagram is

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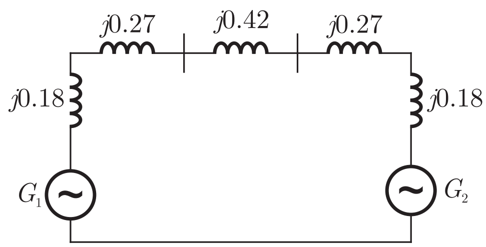
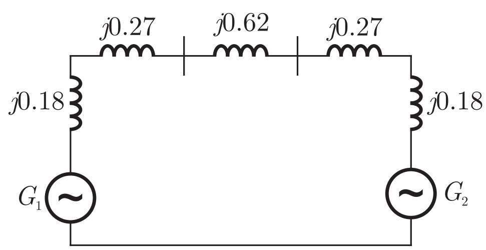
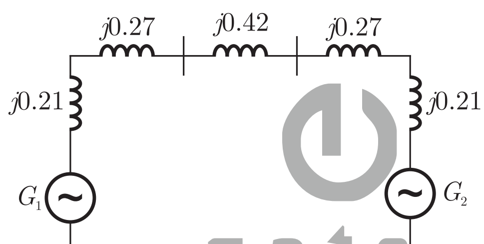
(A)



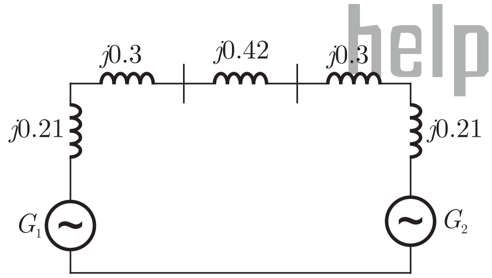
(B)



(C)



(D)



YEAR 2009 **ONE MARK**

MCQ 5.25 Out of the following plant categories

(i) Nuclear

(ii) Run-of-river

(iii) Pump Storage

(iv) Diesel

The base load power plant are

(A) (i) and (ii)

(B) (ii) and (iii)

(C) (i), (ii) and (iv)

(D) (i), (iii) and (iv)

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MCQ 5.26 For a fixed value of complex power flow in a transmission line having a sending end voltage V, the real loss will be proportional to

(A) V
(B) V^2
(C) $\frac{1}{V^2}$
(D) $\frac{1}{V}$

YEAR 2009 TWO MARKS

MCQ 5.27 For the Y-bus matrix of a 4-bus system given in per unit, the buses having shunt elements are

$$Y_{\text{BUS}} = j\begin{bmatrix} -5 & 2 & 2.5 & 0 \\ 2 & -10 & 2.5 & 4 \\ 2.5 & 2.5 & -9 & 4 \\ 0 & 4 & 4 & -8 \end{bmatrix}$$

(A) 3 and 4
(B) 2 and 3
(C) 1 and 2
(D) 1, 2 and 4

MCQ 5.28 Match the items in List-I (To) with the items in the List-II (Use) and select the correct answer using the codes given below the lists.

	List-I		List-II
a.	improve power factor	**1.**	shunt reactor
b.	reduce the current ripples	**2.**	shunt capacitor
c.	increase the power flow in line	**3.**	series capacitor
d.	reduce the Ferranti effect	**4.**	series reactor

(A) $a \rightarrow 2, b \rightarrow 3, c \rightarrow 4, d \rightarrow 1$
(B) $a \rightarrow 2, b \rightarrow 4, c \rightarrow 3, d \rightarrow 1$
(C) $a \rightarrow 4, b \rightarrow 3, c \rightarrow 1, d \rightarrow 2$
(D) $a \rightarrow 4, b \rightarrow 1, c \rightarrow 3, d \rightarrow 2$

MCQ 5.29 Match the items in List-I (Type of transmission line) with the items in List-II (Type of distance relay preferred) and select the correct answer using the codes given below the lists.

	List-I		List-II
a.	Short Line	**1.**	Ohm Relay
b.	Medium Line	**2.**	Reactance Relay
c.	Long Line	**3.**	Mho Relay

(A) $a \rightarrow 2, b \rightarrow 1, c \rightarrow 3$
(B) $a \rightarrow 3, b \rightarrow 2, c \rightarrow 1$
(C) $a \rightarrow 1, b \rightarrow 2, c \rightarrow 3$
(D) $a \rightarrow 1, b \rightarrow 3, c \rightarrow 2$

MCQ 5.30 Three generators are feeding a load of 100 MW. The details of the generators are

	Rating (MW)	Efficiency (%)	Regulation (Pu.) (on 100 MVA base)
Generator-1	100	20	0.02
Generator-2	100	30	0.04
Generator-3	100	40	0.03

In the event of increased load power demand, which of the following will happen ?

(A) All the generator will share equal power

(B) Generator-3 will share more power compared to Generator-1

(C) Generator-1 will share more power compared to Generator-2

(D) Generator-2 will share more power compared to Generator-3

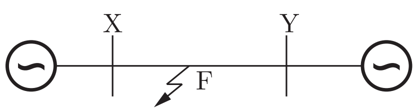
MCQ 5.31 A 500 MW, 21 kV, 50 Hz, 3-phase, 2-pole synchronous generator having a rated p.f $= 0.9$, has a moment of inertia of 27.5×10^3 kg-m^2 .The inertia constant (H) will be

(A) 2.44 s (B) 2.71 s

(C) 4.88 s (D) 5.42 s

YEAR 2008 ONE MARK

MCQ 5.32 A two machine power system is shown below. The Transmission line XY has positive sequence impedance of $Z_1\,\Omega$ and zero sequence impedance of $Z_0\,\Omega$



An 'a' phase to ground fault with zero fault impedance occurs at the centre of the transmission line. Bus voltage at X and line current from X to F for the phase 'a', are given by V_a Volts and I_a amperes, respectively. Then, the impedance measured by the ground distance relay located at the terminal X of line XY will be given by

(A) $(Z_1/2)\,\Omega$ (B) $(Z_0/2)\,\Omega$

(C) $(Z_0 + Z_1)/2\,\Omega$ (D) $(V_a/I_a)\,\Omega$

MCQ 5.33 An extra high voltage transmission line of length 300 km can be approximate by a lossless line having propagation constant $\beta = 0.00127$ radians per km. Then the percentage ratio of line length to wavelength will be given by

(A) 24.24 % (B) 12.12 %

(C) 19.05 % (D) 6.06 %

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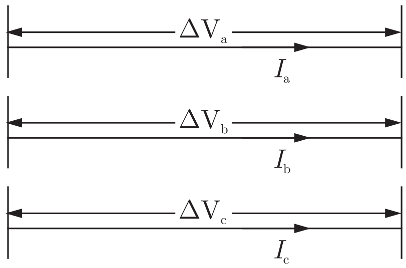
MCQ 5.34 A-3-phase transmission line is shown in figure :



Voltage drop across the transmission line is given by the following equation :

$$\begin{bmatrix} \Delta V_a \\ \Delta V_b \\ \Delta V_c \end{bmatrix} = \begin{bmatrix} Z_s & Z_m & Z_m \\ Z_m & Z_s & Z_m \\ Z_m & Z_m & Z_s \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

Shunt capacitance of the line can be neglect. If the has positive sequence impedance of 15 Ω and zero sequence impedance of 48 Ω, then the values of Z_s and Z_m will be

(A) $Z_s = 31.5\,\Omega; Z_m = 16.5\,\Omega$

(B) $Z_s = 26\,\Omega; Z_m = 11\,\Omega$

(C) $Z_s = 16.5\,\Omega; Z_m = 31.5\,\Omega$

(D) $Z_s = 11\,\Omega; Z_m = 26\,\Omega$

YEAR 2008 **TWO MARKS**

MCQ 5.35 Voltages phasors at the two terminals of a transmission line of length 70 km have a magnitude of 1.0 per unit but are 180 degree out of phase. Assuming that the maximum load current in the line is $1/5^{th}$
of minimum 3-phase fault current. Which one of the following transmission line protection schemes will not pick up for this condition ?

(A) Distance protection using ohm relay with zoen-1 set to 80% of the line impedance.

(B) Directional over current protection set to pick up at 1.25 times the maximum load current

(C) Pilot relaying system with directional comparison scheme

(D) Pilot relaying system with segregated phase comparison scheme

MCQ 5.36 A loss less transmission line having Surge Impedance Loading (SIL) of 2280 MW is provided with a uniformly distributed series capacitive compensation of 30%. Then, SIL of the compensated transmission line will be

(A) 1835 MW (B) 2280 MW

(C) 2725 MW (D) 3257 MW

MCQ 5.37 A loss less power system has to serve a load of 250 MW. There are tow generation (G_1 and G_2) in the system with cost curves C_1 and C_2 respectively defined as follows ;

$C_1(P_{G1}) = P_{G1} + 0.055 \times P_{G1}^2$

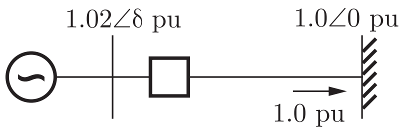
$C_2(P_{G2}) = 3P_{G2} + 0.03 \times P_{G2}^2$

Where P_{G1} and P_{G2} are the MW injections from generator G_1 and G_2 respectively. Thus, the minimum cost dispatch will be

(A) $P_{G1} = 250$ MW; $P_{G2} = 0$ MW (B) $P_{G1} = 150$ MW; $P_{G2} = 100$ MW

(C) $P_{G1} = 100$ MW; $P_{G2} = 150$ MW (D) $P_{G1} = 0$ MW; $P_{G2} = 250$ MW

MCQ 5.38 A loss less single machine infinite bus power system is shown below :



The synchronous generator transfers 1.0 per unit of power to the infinite bus. The critical clearing time of circuit breaker is 0.28 s. If another identical synchronous generator is connected in parallel to the existing generator and each generator is scheduled to supply 0.5 per unit of power, then the critical clearing time of the circuit breaker will

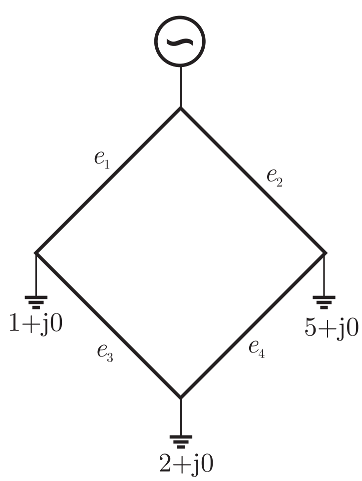
(A) reduce to 0.14 s

(B) reduce but will be more than 0.14 s

(C) remain constant at 0.28 s

(D) increase beyond 0.28 s

MCQ 5.39 Single line diagram of a 4-bus single source distribution system is shown below. Branches e_1, e_2, e_3 and e_4 have equal impedances. The load current values indicated in the figure are in per unit.

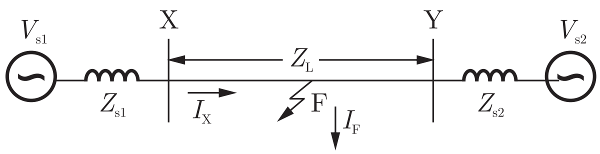


Distribution company's policy requires radial system operation with minimum loss. This can be achieved by opening of the branch

(A) e_1 (B) e_2

(C) e_3 (D) e_4

Data for Q.40 and Q.41 are given below. Solve the problems and choose the correct answers.



Given that: $V_{s1} = V_{s2} = 1 + j0$ p.u;
The positive sequence impedance are
$Z_{s1} = Z_{s2} = 0.001 + j0.01$ p.u and $Z_L = 0.006 + j0.06$ p.u
3-phase Base MVA = 100
voltage base = 400 kV(Line to Line)
Nominal system frequency= 50 Hz.
The reference voltage for phase 'a' is defined as $V(t) = V_m \cos(\omega t)$.
A symmetrical three phase fault occurs at centre of the line, i.e. point 'F' at time 't_0'. The positive sequence impedance from source S_1 to point 'F' equals $0.004 + j0.04$ p.u. The wave form corresponding to phase 'a' fault current from bus X reveals that decaying d.c. offset current is negative and in magnitude at its maximum initial value, Assume that the negative sequence impedances are equal to positive sequence impedance and the zero sequence impedances are three times positive sequence impedances.

MCQ 5.40 The instant (t_0) of the fault will be

(A) 4.682 ms (B) 9.667 ms

(C) 14.667 ms (D) 19.667 ms

MCQ 5.41 The rms value of the component of fault current (I_f) will be

(A) 3.59 kA (B) 5.07 kA

(C) 7.18 kA (D) 10.15 kA

MCQ 5.42 Instead of the three phase fault, if a single line to ground fault occurs on phase 'a' at point 'F' with zero fault impedance, then the rms of the ac component of fault current (I_x) for phase 'a' will be

(A) 4.97 p.u (B) 7.0 p.u

(C) 14.93 p.u (D) 29.85 p.u

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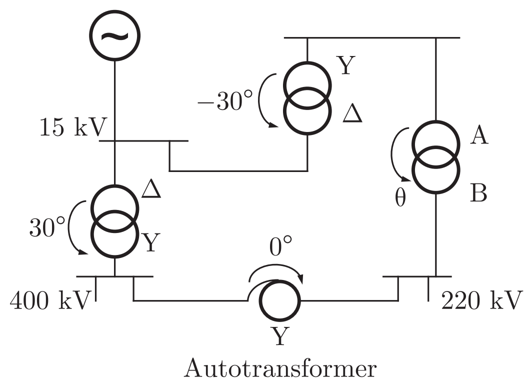
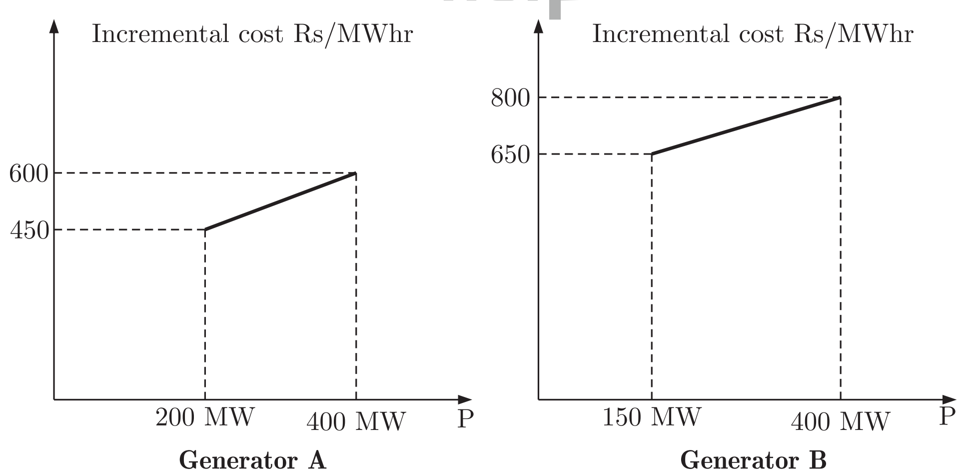
YEAR 2007 ONE MARK

MCQ 5.43 Consider the transformer connections in a part of a power system shown in the figure. The nature of transformer connections and phase shifts are indicated for all but one transformer
Which of the following connections, and the corresponding phase shift θ, should be used for the transformer between A and B ?



(A) Star-star ($\theta = 0^\circ$)
(B) Star-Delta ($\theta = -30^\circ$)
(C) Delta-star ($\theta = 30^\circ$)
(D) Star-Zigzag ($\theta = 30^\circ$)

MCQ 5.44 The incremental cost curves in Rs/MWhr for two generators supplying a common load of 700 MW are shown in the figures. The maximum and minimum generation limits are also indicated. The optimum generation schedule is :



(A) Generator A : 400 MW, Generator B : 300 MW
(B) Generator A : 350 MW, Generator B : 350 MW
(C) Generator A : 450 MW, Generator B : 250 MW
(D) Generator A : 425 MW, Generator B : 275 MW

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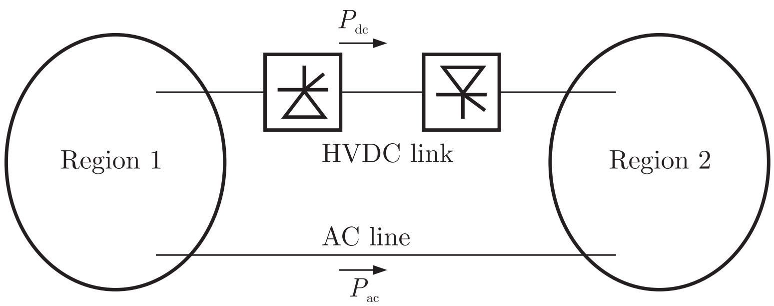
MCQ 5.45 Two regional systems, each having several synchronous generators and loads are inter connected by an ac line and a HVDC link as shown in the figure. Which of the following statements is true in the steady state :



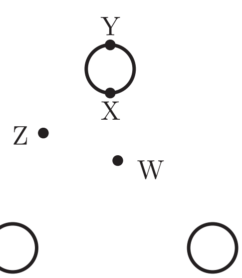
(A) Both regions need not have the same frequency

(B) The total power flow between the regions ($P_{ac} + P_{dc}$) can be changed by controlled the HDVC converters alone

(C) The power sharing between the ac line and the HVDC link can be changed by controlling the HDVC converters alone.

(D) The directions of power flow in the HVDC link (P_{dc}) cannot be reversed

MCQ 5.46 Considered a bundled conductor of an overhead line consisting of three identical sub-conductors placed at the corners of an equilateral triangle as shown in the figure. If we neglect the charges on the other phase conductor and ground, and assume that spacing between sub-conductors is much larger than their radius, the maximum electric field intensity is experienced at



(A) Point X (B) Point Y

(C) Point Z (D) Point W

YEAR 2007 TWO MARKS

MCQ 5.47 The figure below shows a three phase self-commutated voltage source converter connected to a power system. The converter's dc bus capacitor is marked as C in the figure. The circuit in initially operating in steady state with $\delta = 0$ and the capacitor dc voltage is equal to V_{dc0}. You may neglect all

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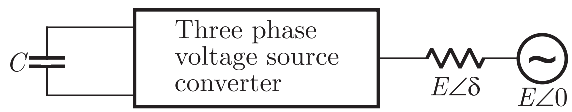
losses and harmonics. What action should be taken to increase the capacitor dc voltage slowly to a new steady state value.



(A) Make δ positive and maintain it at a positive value

(B) Make δ positive and return it to its original value

(C) Make δ negative and maintain it at a negative value

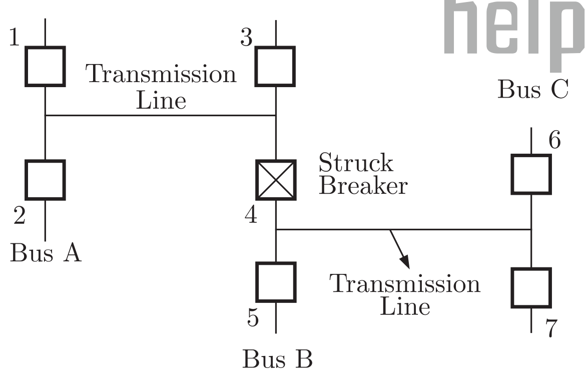
(D) Make δ negative and return it to its original value

MCQ 5.48 The total reactance and total suspectance of a lossless overhead EHV line, operating at 50 Hz, are given by 0.045 pu and 1.2 pu respectively. If the velocity of wave propagation is 3×10^5 km/s, then the approximate length of the line is

(A) 122 km (B) 172 km

(C) 222 km (D) 272 km

MCQ 5.49 Consider the protection system shown in the figure below. The circuit breakers numbered from 1 to 7 are of identical type. A single line to ground fault with zero fault impedance occurs at the midpoint of the line (at point F), but circuit breaker 4 fails to operate (''Stuck breaker''). If the relays are coordinated correctly, a valid sequence of circuit breaker operation is



(A) 1, 2, 6, 7, 3, 5 (B) 1, 2, 5, 5, 7, 3

(C) 5, 6, 7, 3, 1, 2 (D) 5, 1, 2, 3, 6, 7

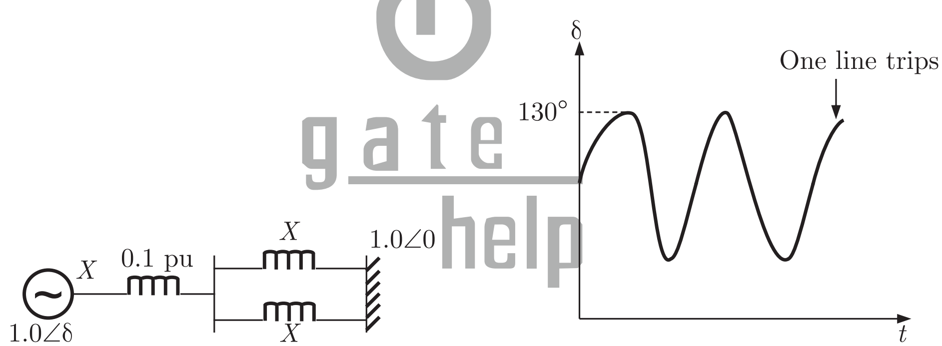
MCQ 5.50 A three phase balanced star connected voltage source with frequency ω rad/s is connected to a star connected balanced load which is purely inductive. The instantaneous line currents and phase to neutral voltages are denoted by (i_a, i_b, i_c) and (V_{an}, V_{bn}, V_{cn}) respectively, and their rms values are denoted by V and I.

If $R = \begin{bmatrix} V_{an} & V_{bn} & V_{cn} \end{bmatrix} \begin{bmatrix} 0 & \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{3}} \\ -\frac{1}{\sqrt{3}} & 0 & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{3}} & 0 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$, then the magnitude of of R is

(A) $3VI$ (B) VI

(C) $0.7VI$ (D) 0

MCQ 5.51 Consider a synchronous generator connected to an infinite bus by two identical parallel transmission line. The transient reactance 'x' of the generator is 0.1 pu and the mechanical power input to it is constant at 1.0 pu. Due to some previous disturbance, the rotor angle (δ) is undergoing an undamped oscillation, with the maximum value of $\delta(t)$ equal to 130° .One of the parallel lines trip due to the relay maloperation at an instant when $\delta(t) = 130^\circ$ as shown in the figure. The maximum value of the per unit line reactance, x such that the system does not lose synchronism subsequent to this tripping is



(A) 0.87 (B) 0.74

(C) 0.67 (D) 0.54

MCQ 5.52 Suppose we define a sequence transformation between "a-b-c" and "p-n-o" variables as follows :

$$\begin{bmatrix} f_a \\ f_b \\ f_c \end{bmatrix} = k \begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix} \begin{bmatrix} f_p \\ f_n \\ f_o \end{bmatrix}$$ where $\alpha = e^{j\frac{2\pi}{3}}$ and k and is a constant

Now, if it is given that : $\begin{bmatrix} V_p \\ V_n \\ V_o \end{bmatrix} = \begin{bmatrix} 0.5 & 0 & 0 \\ 0 & 0.5 & 0 \\ 0 & 0 & 2.0 \end{bmatrix} \begin{bmatrix} i_p \\ i_n \\ i_0 \end{bmatrix}$ and $\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = Z \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$ then,

(A) $Z = \begin{bmatrix} 1.0 & 0.5 & 0.75 \\ 0.75 & 1.0 & 0.5 \\ 0.5 & 0.75 & 1.0 \end{bmatrix}$ (B) $Z = \begin{bmatrix} 1.0 & 0.5 & 0.5 \\ 0.5 & 1.0 & 0.5 \\ 0.5 & 0.5 & 1.0 \end{bmatrix}$

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(C) $Z = 3k^2\begin{bmatrix} 1.0 & 0.75 & 0.5 \\ 0.5 & 1.0 & 0.75 \\ 0.75 & 0.5 & 1.0 \end{bmatrix}$ (D) $Z = \frac{k^2}{3}\begin{bmatrix} 1.0 & -0.5 & -0.5 \\ -0.5 & 1.0 & -0.5 \\ -0.5 & -0.5 & 1.0 \end{bmatrix}$

MCQ 5.53 Consider the two power systems shown in figure A below, which are initially not interconnected, and are operating in steady state at the same frequency. Separate load flow solutions are computed individually of the two systems, corresponding to this scenario. The bus voltage phasors so obtain are indicated on figure A.

These two isolated systems are now interconnected by a short transmission line as shown in figure B, and it is found that $P_1 = P_2 = Q_1 = Q_2 = 0$.

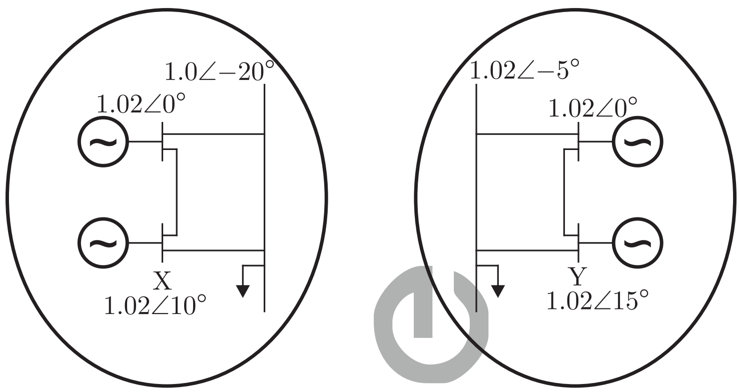

Fig A

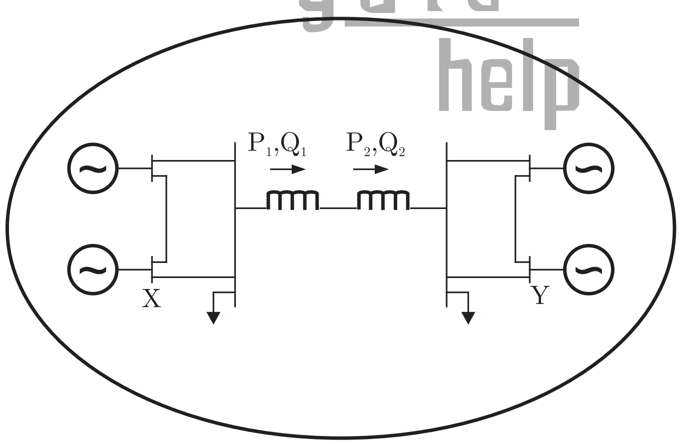

Fig B

The bus voltage phase angular difference between generator bus X and generator bus Y after interconnection is

(A) $10°$ (B) $25°$

(C) $-30°$ (D) $30°$

MCQ 5.54 A 230 V (Phase), 50 Hz, three-phase, 4-wire, system has a phase sequence ABC. A unity power-factor load of 4 kW is connected between phase A and neutral N. It is desired to achieve zero neutral current through the use of a pure inductor and a pure capacitor in the other two phases. The value of inductor and capacitor is

(A) 72.95 mH in phase C and 139.02 μF in Phase B

(B) 72.95 mH in Phase B and 139.02 μF in Phase C

(C) 42.12 mH in Phase C and 240.79 μF in Phase B

(D) 42.12 mH in Phase B and 240.79 μF in Phase C

MCQ 5.55 An isolated 50 Hz synchronous generator is rated at 15 MW which is also the maximum continuous power limit of its prime mover. It is equipped with a speed governor with 5% droop. Initially, the generator is feeding three loads of 4 MW each at 50 Hz. One of these loads is programmed to trip permanently if the frequency falls below 48 Hz .If an additional load of 3.5 MW is connected then the frequency will settle down to

(A) 49.417 Hz (B) 49.917 Hz

(C) 50.083 Hz (D) 50.583 Hz

YEAR 2006 ONE MARK

MCQ 5.56 The concept of an electrically short, medium and long line is primarily based on the

(A) nominal voltage of the line

(B) physical length of the line

(C) wavelength of the line

(D) power transmitted over the line

MCQ 5.57 Keeping in view the cost and overall effectiveness, the following circuit breaker is best suited for capacitor bank switching

(A) vacuum (B) air blast

(C) SF_6 (D) oil

MCQ 5.58 In a biased differential relay the bias is defined as a ratio of

(A) number of turns of restraining and operating coil

(B) operating coil current and restraining coil current

(C) fault current and operating coil current

(D) fault current and restraining coil current

MCQ 5.59 An HVDC link consist of rectifier, inverter transmission line and other equipments. Which one of the following is true for this link ?

(A) The transmission line produces/ supplies reactive power

(B) The rectifier consumes reactive power and the inverter supplies reactive

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power from/ to the respective connected AC systems

(C) Rectifier supplies reactive power and the inverted consumers reactive power to/ from the respective connected AC systems

(D) Both the converters (rectifier and inverter) consume reactive power from the respective connected AC systems

YEAR 2006 TWO MARKS

MCQ 5.60 The A, B, C, D constants of a 220 kV line are :

$A = D = 0.94\angle 1^\circ$, $B = 130\angle 73^\circ$, $C = 0.001\angle 90^\circ$

If the sending end voltage of the line for a given load delivered at nominal voltage is 240 kV, the % voltage regulation of the line is

(A) 5 (B) 9

(C) 16 (D) 21

MCQ 5.61 A single phase transmission line and a telephone line are both symmetrically strung one below the other, in horizontal configurations, on a common tower, The shortest and longest distances between the phase and telephone conductors are 2.5 m and 3 m respectively.

The voltage (volt/km) induced in the telephone circuit, due to 50 Hz current of 100 amps in the power circuit is

(A) 4.81 (B) 3.56

(C) 2.29 (D) 1.27

MCQ 5.62 Three identical star connected resistors of 1.0 pu are connected to an unbalanced 3-phase supply. The load neutral is isolated. The symmetrical components of the line voltages in pu. are: $V_{ab_1} = X\angle\theta_1$, $V_{ab_2} = Y\angle\theta_2$. If all the pu calculations are with the respective base values, the phase to neutral sequence voltages are

(A) $V_{an_1} = X\angle(\theta_1 + 30^\circ), V_{an_2} = Y(\theta_2 - 30^\circ)$

(B) $V_{an_1} = X\angle(\theta_1 - 30^\circ), V_{an_2} = Y\angle(\theta_2 + 30^\circ)$

(C) $V_{an_1} = \frac{1}{\sqrt{3}}X\angle(\theta_1 - 30^\circ), V_{an_2} = \frac{1}{\sqrt{3}}Y\angle(\theta_2 - 30^\circ)$

(D) $V_{an_1} = \frac{1}{\sqrt{3}}X\angle(\theta_1 - 60^\circ), V_{an_2} = \frac{1}{\sqrt{3}}Y\angle(\theta_2 - 60^\circ)$

MCQ 5.63 A generator is connected through a 20 MVA, 13.8/138 kV step down transformer, to a transmission line. At the receiving end of the line a load is supplied through a step down transformer of 10 MVA, 138/69 kV rating. A 0.72 pu. load, evaluated on load side transformer ratings as base values , is supplied from the above system. For system base values of 10 MVA and 69 kV in load circuit, the value of the load (in per unit) in generator will be

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(A) 36 (B) 1.44
(C) 0.72 (D) 0.18

MCQ 5.64 The Gauss Seidel load flow method has following disadvantages. Tick the incorrect statement.
(A) Unreliable convergence
(B) Slow convergence
(C) Choice of slack bus affects convergence
(D) A good initial guess for voltages is essential for convergence

Data for Q. 65 and Q. 66 are given below. Solve the problems and choose the correct answers.

A generator feeds power to an infinite bus through a double circuit transmission line. A 3-phase fault occurs at the middle point of one of the lines. The infinite bus voltage is 1 pu, the transient internal voltage of the generator is 1.1 pu and the equivalent transfer admittance during fault is 0.8 pu. The 100 MVA generator has an inertia constant of 5 MJ/MVA and it was delivering 1.0 pu power prior of the fault with rotor power angle of 30° . The system frequency is 50 Hz.

MCQ 5.65 The initial accelerating power (in pu) will be
(A) 1.0 (B) 0.6
(C) 0.56 (D) 0.4

MCQ 5.66 If the initial accelerating power is X pu, the initial acceleration in elect-deg/sec, and the inertia constant in MJ-sec/elect-deg respectively will be
(A) $31.4X$, 18 (B) $1800X$, 0.056
(C) $X/1800$, 0.056 (D) $X/31.4$, 18

Data for Q.67 and Q.68 are given below. Solve the problems and choose the correct answers.

For a power system the admittance and impedance matrices for the fault studies are as follows.

$$Y_{bus} = \begin{bmatrix} -j8.75 & j1.25 & j2.50 \\ j1.25 & -j6.25 & j2.50 \\ j2.50 & -j2.50 & -j5.00 \end{bmatrix} \qquad Z_{bus} = \begin{bmatrix} j0.16 & j0.08 & j0.12 \\ j0.08 & j0.24 & j0.16 \\ j0.12 & j0.16 & j0.34 \end{bmatrix}$$

The pre-fault voltages are 1.0 pu. at all the buses. The system was unloaded prior to the fault. A solid 3-phase fault takes place at bus 2.

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MCQ 5.67 The post fault voltages at buses 1 and 3 in per unit respectively are

(A) 0.24, 0.63
(B) 0.31, 0.76
(C) 0.33, 0.67
(D) 0.67, 0.33

MCQ 5.68 The per unit fault feeds from generators connected to buses 1 and 2 respectively are

(A) 1.20, 2.51
(B) 1.55, 2.61
(C) 1.66, 2.50
(D) 5.00, 2.50

MCQ 5.69 A 400 V, 50 Hz, three phase balanced source supplies power to a star connected load whose rating is $12\sqrt{3}$ kVA, 0.8 pf (lag). The rating (in kVAR) of the delta connected (capacitive) reactive power bank necessary to bring the pf to unity is

(A) 28. 78
(B) 21.60
(C) 16.60
(D) 12.47

YEAR 2005 ONE MARK

MCQ 5.70 The p.u. parameter for a 500 MVA machine on its own base are:
inertia, $M = 20$ p.u. ; reactance, $X = 2$ p.u.
The p.u. values of inertia and reactance on 100 MVA common base, respectively, are

(A) 4, 0.4
(B) 100, 10
(C) 4, 10
(D) 100, 0.4

MCQ 5.71 An 800 kV transmission line has a maximum power transfer capacity of P . If it is operated at 400 kV with the series reactance unchanged, the new maximum power transfer capacity is approximately

(A) P
(B) $2P$
(C) $P/2$
(D) $P/4$

MCQ 5.72 The insulation strength of an EHV transmission line is mainly governed by

(A) load power factor
(B) switching over-voltages
(C) harmonics
(D) corona

MCQ 5.73 High Voltage DC (HVDC) transmission is mainly used for

(A) bulk power transmission over very long distances
(C) inter-connecting two systems with same nominal frequency
(C) eliminating reactive power requirement in the operation
(D) minimizing harmonics at the converter stations

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YEAR 2005 **TWO MARKS**

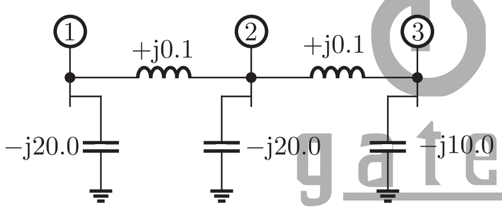
MCQ 5.74 The parameters of a transposed overhead transmission line are given as : Self reactance $X_S = 0.4\Omega/\text{km}$ and Mutual reactance $X_m = 0.1\Omega/\text{km}$ The positive sequence reactance X_1 and zero sequence reactance X_0, respectively in Ω/km are

(A) 0.3, 0.2
(B) 0.5, 0.2
(C) 0.5, 0.6
(D) 0.3, 0.6

MCQ 5.75 At an industrial sub-station with a 4 MW load, a capacitor of 2 MVAR is installed to maintain the load power factor at 0.97 lagging. If the capacitor goes out of service, the load power factor becomes

(A) 0.85
(B) 1.00
(C) 0.80 lag
(D) 0.90 lag

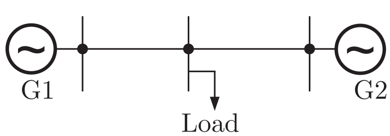
MCQ 5.76 The network shown in the given figure has impedances in p.u. as indicated. The diagonal element Y_{22} of the bus admittance matrix Y_{BUS} of the network is



(A) $-j19.8$
(B) $+j20.0$
(C) $+j0.2$
(D) $-j19.95$

MCQ 5.77 A load centre is at an equidistant from the two thermal generating stations G_1 and G_2 as shown in the figure. The fuel cost characteristic of the generating stations are given by

$F_1 = a + bP_1 + cP_1^2$ Rs/hour
$F_2 = a + bP_2 + 2cP_2^2$ Rs/ hour



Where P_1 and P_2 are the generation in MW of G_1 and G_2, respectively. For most economic generation to meet 300 MW of load P_1 and P_2 respectively, are

(A) 150, 150
(B) 100, 200
(C) 200, 100
(D) 175, 125

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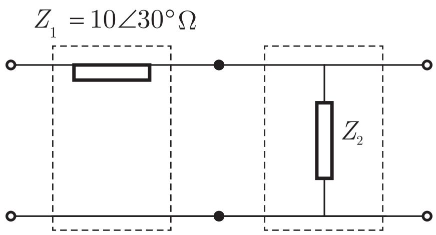
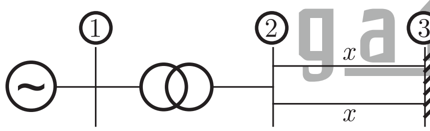
MCQ 5.78 Two networks are connected in cascade as shown in the figure. With usual notations the equivalent A, B, C and D constants are obtained. Given that, $C = 0.025\angle 45°$, the value of Z_2 is



(A) $10\angle 30°\,\Omega$
(B) $40\angle -45°\,\Omega$
(C) $1\,\Omega$
(D) $0\,\Omega$

MCQ 5.79 A generator with constant 1.0 p.u. terminal voltage supplies power through a step-up transformer of 0.12 p.u. reactance and a double-circuit line to an infinite bus bar as shown in the figure. The infinite bus voltage is maintained at 1.0 p.u. Neglecting the resistances and suspectances of the system, the steady state stability power limit of the system is 6.25 p.u. If one of the double-circuit is tripped, then resulting steady state stability power limit in p.u. will be



(A) 12.5 p.u.
(B) 3.125 p.u.
(C) 10.0 p.u.
(D) 5.0 p.u.

Data for Q.80 and Q.81 are given below. Solve the problems and choose the correct answers

At a 220 kV substation of a power system, it is given that the three-phase fault level is 4000 MVA and single-line to ground fault level is 5000 MVA Neglecting the resistance and the shunt suspectances of the system.

MCQ 5.80 The positive sequence driving point reactance at the bus is
(A) 2.5 Ω
(B) 4.033 Ω
(C) 5.5 Ω
(D) 12.1 Ω

MCQ 5.81 The zero sequence driving point reactance at the bus is
(A) 2.2 Ω
(B) 4.84 Ω
(C) 18.18 Ω
(D) 22.72 Ω

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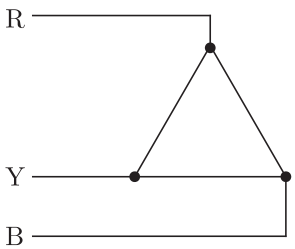
MCQ 5.82 Total instantaneous power supplied by a 3-phase ac supply to a balanced R-L load is
(A) zero
(B) constant
(C) pulsating with zero average
(D) pulsating with the non-zero average

MCQ 5.83 The rated voltage of a 3-phase power system is given as
(A) rms phase voltage
(B) peak phase voltage
(C) rms line to line voltage
(D) peak line to line voltage

MCQ 5.84 The phase sequences of the 3-phase system shown in figure is



(A) RYB
(B) RBY
(C) BRY
(D) YBR

MCQ 5.85 In the thermal power plants, the pressure in the working fluid cycle is developed by
(A) condenser
(B) super heater
(C) feed water pump
(D) turbine

MCQ 5.86 For harnessing low variable waterheads, the suitable hydraulic turbine with high percentage of reaction and runner adjustable vanes is
(A) Kaplan
(B) Francis
(C) Pelton
(D) Impeller

MCQ 5.87 The transmission line distance protection relay having the property of being inherently directional is
(A) impedance relay
(B) MHO relay
(C) OHM relay
(D) reactance relay

YEAR 2004 TWO MARKS

MCQ 5.88 A 800 kV transmission line is having per phase line inductance of

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1.1 mH/km and per phase line capacitance of 11.68 nF/km. Ignoring the length of the line, its ideal power transfer capability in MW is

(A) 1204 MW (B) 1504 MW

(C) 2085 MW (D) 2606 MW

MCQ 5.89 A 110 kV, single core coaxial, XLPE insulated power cable delivering power at 50 Hz, has a capacitance of 125 nF/km. If the dielectric loss tangent of XLPE is 2×10^{-4}, then dielectric power loss in this cable in W/km is

(A) 5.0 (B) 31.7

(C) 37.8 (D) 189.0

MCQ 5.90 A lightning stroke discharges impulse current of 10 kA (peak) on a 400 kV transmission line having surge impedance of 250 Ω The magnitude of transient over-voltage travelling waves in either direction assuming equal distribution from the point of lightning strike will be

(A) 1250 kV (B) 1650 kV

(C) 2500 kV (D) 2900 kV

MCQ 5.91 The generalized circuit constants of a 3-phase, 220 kV rated voltage, medium length transmission line are

$$A = D = 0.936 + j0.016 = 0.936\angle 0.98^\circ$$
$$B = 35.5 + j138 = 142.0\angle 76.4^\circ\ \Omega$$
$$C = (-5.18 + j914)\times10^{-6}\ \Omega$$

If the load at the receiving end is 50 MW at 220 kV with a power factor of 0.9 lagging, then magnitude of line to line sending end voltage should be

(A) 133.23 kV (B) 220.00 kV

(C) 230. 78 kV (D) 246.30 kV

MCQ 5.92 A new generator having $E_g = 1.4\angle 30^\circ$ pu. [equivalent to $(1.212 + j0.70)$ pu] and synchronous reactance 'X_S' of 1.0 pu on the system base, is to be connected to a bus having voltage V_t, in the existing power system. This existing power system can be represented by Thevenin's voltage $E_{th} = 0.9\angle 0^\circ$ pu in series with Thevenin's impedance $Z_{th} = 0.25\angle 90^\circ$ pu. The magnitude of the bus voltage V_t of the system in pu will be

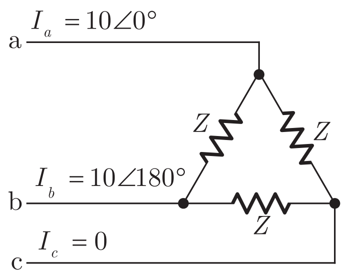
(A) 0.990 (B) 0.973

(C) 0.963 (D) 0.900

MCQ 5.93 A 3-phase generator rated at 110 MVA, 11 kV is connected through circuit breakers to a transformer . The generator is having direct axis sub-transient reactance $X''_d = 19\%$, transient reactance $X'_d = 26\%$ and synchronous reactance =130%. The generator is operating at no load and rated voltage when a three phase short circuit fault occurs between the breakers and the transformer . The magnitude of initial symmetrical rms current in the breakers will be

(A) 4.44 kA
(B) 22.20 kA
(C) 30.39 kA
(D) 38.45 kA

MCQ 5.94 A 3-phase transmission line supplies Δ-connected load Z. The conductor 'c' of the line develops an open circuit fault as shown in figure. The currents in the lines are as shown on the diagram. The +ve sequence current component in line 'a' will be



(A) $5.78\angle -30°$
(B) $5.78\angle 90°$
(C) $6.33\angle 90°$
(D) $10.00\angle -30°$

MCQ 5.95 A 500 MVA, 50 Hz, 3-phase turbo-generator produces power at 22 kV. Generator is Y-connected and its neutral is solidly grounded. It sequence reactances are $X_1 = X_2 = 0.15$ pu and $X_0 = 0.05$ pu.It is operating at rated voltage and disconnected from the rest of the system (no load). The magnitude of the sub-transient line current for single line to ground fault at the generator terminal in pu will be

(A) 2.851
(B) 3.333
(C) 6.667
(D) 8.553

MCQ 5.96 A 50 Hz, 4-pole, 500 MVA, 22 kV turbo-generator is delivering rated megavolt-amperes at 0.8 power factor. Suddenly a fault occurs reducing in electric power output by 40%. Neglect losses and assume constant power input to the shaft. The accelerating torque in the generator in MNm at the time of fault will be

(A) 1.528
(B) 1.018
(C) 0.848
(D) 0.509

MCQ 5.97 A hydraulic turbine having rated speed of 250 rpm is connected to a synchronous generator. In order to produce power at 50 Hz, the number of poles required in the generator are

(A) 6
(B) 12
(C) 16
(D) 24

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YEAR 2003 ONE MARK

MCQ 5.98 Bundled conductors are mainly used in high voltage overhead transmission lines to

(A) reduces transmission line losses

(B) increase mechanical strength of the line

(C) reduce corona

(D) reduce sag

MCQ 5.99 A power system consist of 300 buses out of which 20 buses are generator bus, 25 buses are the ones with reactive power support and 15 buses are the ones with fixed shunt capacitors. All the other buses are load buses. It is proposed to perform a load flow analysis in the system using Newton-Raphson method. The size of the Newton Raphson Jacobian matrix is

(A) 553×553 (B) 540×540

(C) 555×555 (D) 554×554

MCQ 5.100 Choose two appropriate auxiliary components of a HVDC transmission system from the following

P. D.C line inductor

Q. A.C line inductor

R. Reactive power sources

S. Distance relays on D.C line

T. Series capacitance on A.C. line

(A) P and Q (B) P and R

(C) Q and S (D) S and T

MCQ 5.101 A round rotor generator with internal voltage $E_1 = 2.0$ pu and $X = 1.1$ pu is connected to a round rotor synchronous motor with internal voltage $E_2 = 1.3$ pu and $X = 1.2$ pu. The reactance of the line connecting the generator to the motor is 0.5 pu. When the generator supplies 0.5 pu power, the rotor angle difference between the machines will be

(A) $57.42°$ (B) $1°$

(C) $32.58°$ (D) $122.58°$

MCQ 5.102 The interrupting time of a circuit breaker is the period between the instant of

(A) initiation of short circuit and the arc extinction on an opening operation

(B) energizing of the trip circuit and the arc extinction on an opening operation

(C) initiation of short circuit and the parting of primary arc contacts

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(D) energizing of the trip circuit and the parting of primary arc contacts

YEAR 2003 **TWO MARKS**

MCQ 5.103 The *ABCD* parameters of a 3-phase overhead transmission line are $A = D = 0.9\angle 0°, B = 200\angle 90°\,\Omega$ and $C = 0.95 \times 10^{-3}\angle 90°$ S. At no-load condition a shunt inductive, reactor is connected at the receiving end of the line to limit the receiving-end voltage to be equal to the sending-end voltage. The ohmic value of the reactor is

(A) $\infty\,\Omega$ (B) $2000\,\Omega$

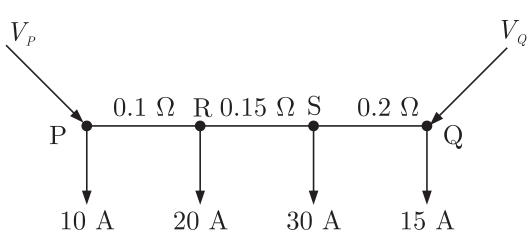
(C) $105.26\,\Omega$ (D) $1052.6\,\Omega$

MCQ 5.104 A surge of 20 kV magnitude travels along a lossless cable towards its junction with two identical lossless overhead transmission lines. The inductance and the capacitance of the cable are 0.4 mH and 0.5 μF per km. The inductance and capacitance of the overhead transmission lines are 1.5 mH and 0.015 μF per km. The magnitude of the voltage at the junction due to surge is

(A) 36.72 kV (B) 18.36 kV

(C) 6.07 kV (D) 33.93 kV

MCQ 5.105 A dc distribution system is shown in figure with load current as marked. The two ends of the feeder are fed by voltage sources such that $V_P - V_Q = 3$ V. The value of the voltage V_P for a minimum voltage of 220 V at any point along the feeder is



(A) 225.89 V (B) 222.89 V

(C) 220.0 V (D) 228.58 V

MCQ 5.106 A 3-phase 11 kV generator feeds power to a constant power unity power factor load of 100 MW through a 3-phase transmission line. The line-to line voltage at the terminals of the machine is maintained constant at 11 kV. The per unit positive sequence impedance of the line based on 100 MVA and 11 kV is *j*0.2. The line to line voltage at the load terminals is measured to be less than 11 kV. The total reactive power to be injected at the terminals of the load to increase the line-to-line voltage at the load terminals to 11 kV is

(A) 100 MVAR (B) 10.1 MVAR
(C) -100 MVAR (D) -10.1 MVAR

MCQ 5.107 The bus impedance matrix of a 4-bus power system is given by

$$Z_{bus} = \begin{bmatrix} j0.3435 & j0.2860 & j0.2723 & j0.2277 \\ j0.2860 & j0.3408 & j0.2586 & j0.2414 \\ j0.2723 & j0.2586 & j0.2791 & j0.2209 \\ j0.2277 & j0.2414 & j0.2209 & j0.2791 \end{bmatrix}$$

A branch having an impedance of $j0.2\,\Omega$ is connected between bus 2 and the reference. Then the values of $Z_{22,new}$ and $Z_{23,new}$ of the bus impedance matrix of the modified network are respectively

(A) $j0.5408\ \Omega$ and $j0.4586\ \Omega$

(B) $j0.1260\ \Omega$ and $j0.0956\ \Omega$

(C) $j0.5408\ \Omega$ and $j0.0956\ \Omega$

(D) $j0.1260\ \Omega$ and $j0.1630\ \Omega$

MCQ 5.108 A 20-MVA, 6.6-kV, 3-phase alternator is connected to a 3-phase transmission line. The per unit positive-sequence, negative-sequence and zero-sequence impedances of the alternator are $j0.1$, $j0.1$ and $j0.04$ respectively. The neutral of the alternator is connected to ground through an inductive reactor of $j0.05$ p.u. The per unit positive-, negative- and zero-sequence impedances of transmission line are $j0.1$, $j0.1$ and $j0.3$, respectively. All per unit values are based on the machine ratings. A solid ground fault occurs at one phase of the far end of the transmission line. The voltage of the alternator neutral with respect to ground during the fault is

(A) 513.8 V (B) 889.9 V
(C) 1112.0 V (D) 642.2 V

MCQ 5.109 Incremental fuel costs (in some appropriate unit) for a power plant consisting of three generating units are

$IC_1 = 20 + 0.3P_1$, $IC_2 = 30 + 0.4P_2$, $IC_3 = 30$

Where P_1 is the power in MW generated by unit i for $i = 1,2$ and 3. Assume that all the three units are operating all the time. Minimum and maximum loads on each unit are 50 MW and 300 MW respectively. If the plant is operating on economic load dispatch to supply the total power demand of 700 MW, the power generated by each unit is

(A) $P_1 = 242.86$ MW; $P_2 = 157.14$ MW; and $P_3 = 300$ MW

(B) $P_1 = 157.14$ MW; $P_2 = 242.86$ MW; and $P_3 = 300$ MW

(C) $P_1 = 300$ MW; $P_2 = 300$ MW; and $P_3 = 100$ MW

(D) $P_1 = 233.3$ MW; $P_2 = 233.3$ MW; and $P_3 = 233.4$ MW

MCQ 5.110 A list of relays and the power system components protected by the relays are given in List-I and List-II respectively. Choose the correct match from the four choices given below:

	List-I		**List-II**
P.	Distance relay	**1.**	Transformers
Q.	Under frequency relay	**2.**	Turbines
R.	Differential relay	**3.**	Busbars
S.	Buchholz relay	**4.**	Shunt capacitors
		5.	Alternators
		6.	Transmission lines

Codes:

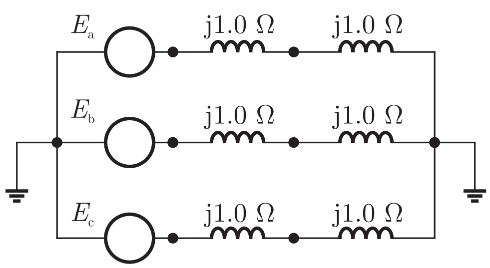
	P	Q	R	S
(A)	6	5	3	1
(B)	4	3	2	1
(C)	5	2	1	6
(D)	6	4	5	3

MCQ 5.111 A generator delivers power of 1.0 p.u. to an infinite bus through a purely reactive network. The maximum power that could be delivered by the generator is 2.0 p.u. A three-phase 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 the rotor angle is found to be $\delta_{max} = 110$ electrical degree. Then the rotor angle in electrical degrees at $t = t_c$ is

(A) 55 (B) 70

(C) 69.14 (D) 72.4

MCQ 5.112 A three-phase alternator generating unbalanced voltages is connected to an unbalanced load through a 3-phase transmission line as shown in figure. The neutral of the alternator and the star point of the load are solidly grounded. The phase voltages of the alternator are $E_a = 10\angle 0^\circ$ V, $E_b = 10\angle -90^\circ$ V, $E_c = 10\angle 120^\circ$ V. The positive-sequence component of the load current is



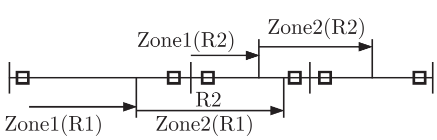
(A) $1.310\angle-107^\circ$ A (B) $0.332\angle-120^\circ$ A
(C) $0.996\angle-120^\circ$ A (D) $3.510\angle-81^\circ$ A

MCQ 5.113 A balanced delta connected load of $(8+j6)\,\Omega$ per phase is connected to a 400 V, 50 Hz, 3-phase supply lines. If the input power factor is to be improved to 0.9 by connecting a bank of star connected capacitor the required kVAR of the of the bank is
(A) 42.7 (B) 10.2
(C) 28.8 (D) 38.4

YEAR 2002 ONE MARK

MCQ 5.114 Consider a power system with three identical generators. The transmission losses are negligible. One generator(G1) has a speed governor which maintains its speed constant at the rated value, while the other generators(G2 and G3) have governors with a droop of 5%. If the load of the system is increased, then in steady state.
(A) generation of G2 and G3 is increased equally while generation of G1 is unchanged.
(B) generation of G1 alone is increased while generation of G2 and G3 is unchanged.
(C) generation of G1, G2 and G3 is increased equally.
(D) generally of G1, G2 and G3 is increased in the ratio 0.5 : 0.25 : 0.25.

MCQ 5.115 Consider the problem of relay co-ordination for the distance relays $R1$ and $R2$ on adjacent lines of a transmission system. The Zone-1 and Zone-2 settings for both the relays are indicated on the diagram. Which of the following indicates the correct time setting for the Zone-2 of relays $R1$ and $R2$.



(A) $TZ2_{R1}=0.6\text{ s}, TZ2_{R2}=0.3\text{ s}$ (B) $TZ2_{R1}=0.3\text{ s}, TZ2_{R2}=0.6\text{ s}$
(C) $TZ2_{R1}=0.3\text{ s}, TZ2_{R2}=0.3\text{ s}$ (D) $TZ2_{R1}=0.1\text{ s}, TZ2_{R2}=0.3\text{ s}$

YEAR 2002 TWO MARKS

MCQ 5.116 A three phase thyristor bridge rectifier is used in a HVDC link. The firing angle α (as measured from the point of natural commutation) is constrained to lie between 5° and 30°. If the dc side current and ac side voltage magnitudes are constant, which of the following statements is true (neglect harmonics in the ac side currents and commutation overlap in your analysis)

(A) Reactive power absorbed by the rectifier is maximum when $\alpha = 5^\circ$

(B) Reactive power absorbed by the rectifier is maximum when $\alpha = 30^\circ$

(C) Reactive power absorbed by the rectifier is maximum when $\alpha = 15^\circ$

(D) Reactive power absorbed by the rectifier is maximum when $\alpha = 15^\circ$

MCQ 5.117 A power system consist of 2 areas (area 1 and area 2) connected by a single tie-line. It is required to carry out a load-flow study on this system. While entering the network data, the tie-line data (connectivity and parameters) is inadvertently left out. If the load flow program is run with this incomplete data

(A) The load-flow will converge only if the slack bus is specified in area 1

(B) The load-flow will converge only if the slack bus is specified in area 2

(C) The load-flow will converge if the slack bus is specified in either area 1 or area 2

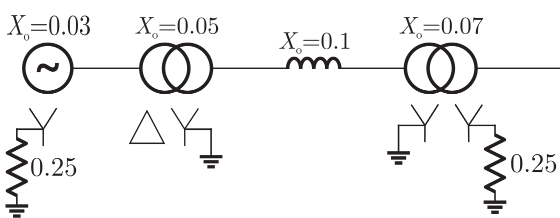
(D) The load-flow will not converge if only one slack is specified.

MCQ 5.118 A transmission line has a total series reactance of 0.2 pu. Reactive power compensation is applied at the midpoint of the line and it is controlled such that the midpoint voltage of the transmission line is always maintained at 0.98 pu. If voltage at both ends of the line are maintained at 1.0 pu, then the steady state power transfer limit of the transmission line is

(A) 9.8 pu (B) 4.9 pu

(C) 19.6 pu (D) 5 pu

MCQ 5.119 A generator is connected to a transformer which feeds another transformer through a short feeder (see figure). The zero sequence impedance values expressed in pu on a common base and are indicated in figure. The Thevenin equivalent zero sequence impedance at point B is



(A) $0.8 + j0.6$ (B) $0.75 + j0.22$

(C) $0.75 + j0.25$ (D) $1.5 + j0.25$

MCQ 5.120 *A long lossless transmission line has a unity power factor(UPF) load at the

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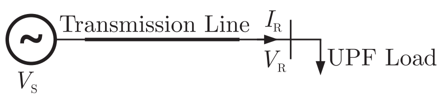
receiving end and an ac voltage source at the sending end. The parameters of the transmission line are as follows :

Characteristic impedance $Z_c = 400\,\Omega$, propagation constant $\beta = 1.2 \times 10^{-3}$ rad/km, and the length $l = 100$ km. The equation relating sending and receiving end questions is

$$V_s = V_r \cos(\beta l) + jZ_c \sin(\beta l)\, I_R$$

Compute the maximum power that can be transferred to the UPF load at the receiving end if $|V_s| = 230$ kV



MCQ 5.121 *Two transposed 3-phase lines run parallel to each other. The equation describing the voltage drop in both lines is given below.

$$\begin{bmatrix} \Delta V_{a1} \\ \Delta V_{b1} \\ \Delta V_{c1} \\ \Delta V_{a2} \\ \Delta V_{b2} \\ \Delta V_{c2} \end{bmatrix} = j \begin{bmatrix} 0.15 & 0.05 & 0.05 & 0.04 & 0.04 & 0.04 \\ 0.05 & 0.15 & 0.05 & 0.04 & 0.04 & 0.04 \\ 0.05 & 0.05 & 0.15 & 0.04 & 0.04 & 0.04 \\ 0.04 & 0.04 & 0.04 & 0.15 & 0.05 & 0.05 \\ 0.04 & 0.04 & 0.04 & 0.05 & 0.15 & 0.05 \\ 0.04 & 0.04 & 0.04 & 0.05 & 0.05 & 0.15 \end{bmatrix} \begin{bmatrix} I_{a1} \\ I_{b1} \\ I_{c1} \\ I_{a2} \\ I_{b2} \\ I_{c2} \end{bmatrix}$$

Compute the self and mutual zero sequence impedance of this system i.e. compute $Z_{011}, Z_{012}, Z_{021}, Z_{022}$ in the following equations.

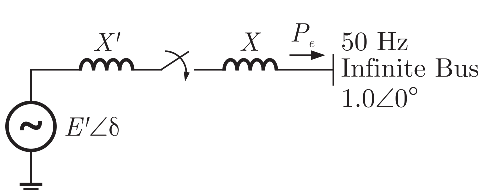
$$\Delta V_{01} = Z_{011} I_{01} + Z_{012} I_{02}$$
$$\Delta V_{02} = Z_{021} I_{01} + Z_{022} I_{02}$$

Where $\Delta V_{01}, \Delta V_{02}, I_{01}, I_{02}$ are the zero sequence voltage drops and currents for the two lines respectively.

MCQ 5.122 *A synchronous generator is to be connected to an infinite bus through a transmission line of reactance $X = 0.2$ pu, as shown in figure. The generator data is as follows :

$x' = 0.1$ pu, $E' = 1.0$ pu, $H = 5$ MJ/MVA , mechanical power $P_m = 0.0$ pu, $\omega_B = 2\pi \times 50$ rad/s. All quantities are expressed on a common base.

The generator is initially running on open circuit with the frequency of the open circuit voltage slightly higher than that of the infinite bus. If at the instant of switch closure, $\delta = 0$ and $\omega = \frac{d\delta}{dt} = \omega_{init}$, compute the maximum value of ω_{init} so that the generator pulls into synchronism.



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Hint : Use the equation $\int (2H/\omega_B)\,\omega d\omega + P_e d\delta = 0$

YEAR 2001 ONE MARK

MCQ 5.123 A lossless radial transmission line with surge impedance loading

(A) takes negative VAR at sending end and zero VAR at receiving end

(B) takes positive VAR at sending end and zero VAR at receiving end

(C) has flat voltage profile and unity power factor at all points along it

(D) has sending end voltage higher than receiving end voltage and unity power factor at sending end

YEAR 2001 TWO MARKS

MCQ 5.124 A 3-phase transformer has rating of 20 MVA, 220 kV(star)-33 kV (delta) with leakage reactance of 12%. The transformer reactance (in ohms) referred to each phase of the L.V. delta-connected side is

(A) 23.5 (B) 19.6

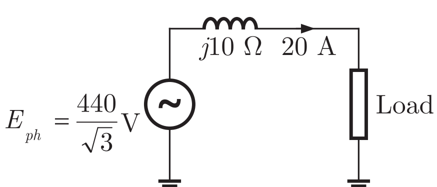
(C) 18.5 (D) 8.7

MCQ 5.125 A 75 MVA, 10 kV synchronous generator has $X_d = 0.4$ pu. The X_d value (in pu) to a base of 100 MVA, 11 kV is

(A) 0.578 (B) 0.279

(C) 0.412 (D) 0.44

MCQ 5.126 A star-connected 440 V, 50 Hz alternator has per phase synchronous reactance of $10\,\Omega$. It supplies a balanced capacitive load current of 20 A, as shown in the per phase equivalent circuit of figure. It is desirable to have zero voltage regulation. The load power factor would be



(A) 0.82 (B) 0.47

(C) 0.39 (D) 0.92

MCQ 5.127 A 240 V single-phase source is connected to a load with an impedance of $10\angle 60^\circ\,\Omega$. A capacitor is connected in parallel with the load. If the capacitor supplies 1250 VAR, the real power supplied by the source is

(A) 3600 W (B) 2880 W

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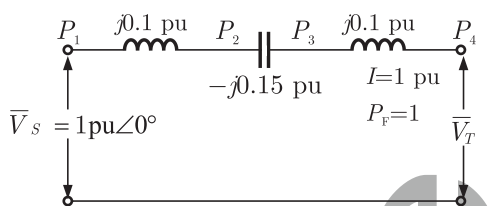
(C) 2400 W (D) 1200 W

MCQ 5.128 A 50 Hz alternator is rated 500 MVA, 20 kV, with $X_d = 1.0$ per unit and $X''_d = 0.2$ per unit. It supplies a purely resistive load of 400 MW at 20 kV. The load is connected directly across the generator terminals when a symmetrical fault occurs at the load terminals. The initial rms current in the generator in per unit is

(A) 7.22 (B) 6.4

(C) 3.22 (D) 2.2

MCQ 5.129 Consider the model shown in figure of a transmission line with a series capacitor at its mid-point. The maximum voltage on the line is at the location



(A) P_1 (B) P_2

(C) P_3 (D) P_4

MCQ 5.130 A power system has two synchronous generators. The Governor-turbine characteristics corresponding to the generators are

$$P_1 = 50(50 - f), P_2 = 100(51 - f)$$

where f denotes the system frequency in Hz, and P_1 and P_2 are, respectively, the power outputs (in MW) of turbines 1 and 2. Assuming the generators and transmission network to be lossless, the system frequency for a total load of 400 MW is

(A) 47.5 Hz (B) 48.0 Hz

(C) 48.5 Hz (D) 49.0 Hz

MCQ 5.131 *A 132 kV transmission line AB is connected to a cable BC. The characteristic impedances of the overhead line and the cable are 400 Ω and 80 Ω respectively. Assume that these are purely resistively. Assume that these are purely resistive. A 250 kV switching surge travels from A to B.

(a) Calculate the value of this voltage surge when it first reaches C

(b) Calculate the value of the reflected component of this surge when the first reflection reaches A.

(c) Calculate the surge current in the cable BC.

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MCQ 5.132 *For the Y-bus matrix given in per unit values, where the first, second, third, and fourth row refers to bus 1, 2, 3 and 4 respectively, draw the reactance diagram.

$$Y_{Bus} = j\begin{bmatrix} -6 & 2 & 2.5 & 0 \\ 2 & -10 & 2.5 & 4 \\ 2.5 & 2.5 & -9 & 4 \\ 0 & 4 & 4 & -8 \end{bmatrix}$$

MCQ 5.133 *A synchronous generator is connected to an infinite bus through a lossless double circuit transmission line. The generator is delivering 1.0 per unit power at a load angle of 30° when a sudden fault reduces the peak power that can be transmitted to 0.5 per unit. After clearance of fault, the peak power that can be transmitted becomes 1.5 per unit. Find the critical clearing angle.

MCQ 5.134 *A single line-to-ground fault occurs on an unloaded generator in phase a positive, negative, and zero sequence impedances of the generator are $j0.25$ pu, $j0.25$ pu, and $j0.15$ pu respectively. The generator neutral is grounded through a reactance of $j0.05$ pu. The prefault generator terminal voltage is 1.0 pu.

(a) Draw the positive, negative, and zero sequence network for the fault given.

(b) Draw the interconnection of the sequence network for the fault analysis.

(c) Determine the fault current

MCQ 5.135 A power system has two generators with the following cost curves

Generator1: $C_1(P_{G1}) = 0.006P^2_{G1} + 8P_{G1} + 350$ (Thousand Rupees/Hour)

Generator2: $C_2(P_{G2}) = 0.009P^2_{G2} + 7P_{G2} + 400$ (Thousand Rupees/ Hour)

The generator limits are

$$100 \text{ MW} \le P_{G1} \le 650 \text{ MW}$$

$$50 \text{ MW} \le P_{G2} \le 500 \text{ MW}$$

A load demand of 600 MW is supplied by the generators in an optimal manner. Neglecting losses in the transmission network, determine the optimal generation of each generator.

****

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SOLUTION

SOL 5.1 Option (B) is correct.

For bus admittance matrix,

$$Y_{11} + (Y_{12} + y_{line}) + Y_{13} = 0$$

$$-j13 + (j10 + y_{line}) + j5 = 0$$

$$y_{line} = -j2$$

Magnitude of susceptance is $+2$

SOL 5.2 Option (A) is correct.

$$i_1(t) = I_m \sin(\omega t - \phi_1)$$

$$i_2(t) = I_m \cos(\omega t - \phi_2)$$

We know that,

$$\cos(\theta - 90^\circ) = \sin\theta$$

So, $i_1(t)$ can be written as

$$i_1(t) = I_m \cos(\omega t - \phi_1 - 90^\circ)$$

$$i_2(t) = I_m \cos(\omega t - \phi_2)$$

Now, in phasor form $\boldsymbol{I}_1 = I_m \angle \phi_1 + 90^\circ$

$$\boldsymbol{I}_2 = I_m \angle \phi_2$$

Current are balanced if $\boldsymbol{I}_1 + \boldsymbol{I}_2 = 0$

$$I_m \angle \phi_1 + 90^\circ + I_m \angle \phi_2 = 0$$

$$I_m \cos(\phi_1 + 90^\circ) + jI_m \sin(\phi_1 + 90^\circ) + \cos\phi_2 + j\sin\phi_2 = 0$$

$$I_m[\cos(\phi_1 + 90^\circ) + j\sin(\phi_1 + 90^\circ)] + I_m[\cos\phi_2 + j\sin\phi_2] = 0$$

$$I_m[\cos(\phi_1 + 90^\circ) + \cos\phi_2] + jI_m[\sin\phi_2 + \sin(\phi_1 + 90^\circ)] = 0$$

$$\cos(\phi_1 + 90^\circ) + \cos\phi_2 = 0$$

$$\cos(\phi_1 + 90^\circ) = -\cos\phi_2 = \cos(\pi + \phi_2)$$

$$\phi_1 + 90^\circ = \pi + \phi_2$$

or,

$$\phi_1 = \frac{\pi}{2} + \phi_2$$

SOL 5.3 Option (A) is correct.

Let penalty factor of plant G, is L_1 given as

$$L_1 = \frac{1}{1 - \frac{\partial P_L}{\partial P_{G_1}}}$$

$$P_L = 0.5P_{G_1}^2$$

$$\frac{\partial P_L}{\partial P_{G_2}} = 0.5(2P_{G_1}) = P_{G_1}$$

So, $$L_1 = \frac{1}{1 - P_{G_2}}$$

Penalty factor of plant G_2 is

$$L_2 = \frac{1}{1 - \frac{\partial P_L}{\partial P_{G_2}}} = 1 \qquad \left(\because \frac{\partial P_L}{\partial P_{G_2}} = 0\right)$$

For economic power generation

$$C_1 \times L_1 = C_2 \times L_2$$

where C_1 and C_2 are the incremental fuel cost of plant G_1 and G_2.

So, $$(10000)\left(\frac{1}{1 - P_{G_2}}\right) = 12500 \times 1$$

$$\frac{4}{5} = 1 - P_{G_2}$$

$$P_{G_2} = \frac{1}{5}\text{ pu}$$

It is an 100 MVA, so $$P_{G_2} = \frac{1}{5} \times 100 = 20\text{ MW}$$

Loss $$P_L = 0.5\left(\frac{1}{5}\right)^2 = \frac{1}{50}\text{ pu}$$

or $$P_L = \frac{1}{50} \times 100 = 2\text{ MW}$$

Total power, $$P_L = P_{G_1} + P_{G_2} - P_L$$

$$40 = 20 + P_2 - 2$$

$$P_{G_2} = 22\text{ MW}$$

SOL 5.4 Option (C) is correct.

For double line-to-ground (LLG) fault, relation between sequence current is

$$I_{\text{positive}} = -(I_{\text{negative}} + I_{\text{zero}})$$

Gives values satisfy this relation, therefore the type of fault is LLG.

SOL 5.5 Option (B) is correct.

Complex power for generator

$$\boldsymbol{S}_{G_1} = \boldsymbol{S}_{D1} + \boldsymbol{S}_{D2} = 1 + 1 = 2\text{ pu} \qquad \text{(Line is lossless)}$$

Power transferred from bus 1 to bus 2 is 1 pu, so

$$1 = \frac{|\boldsymbol{V}_1||\boldsymbol{V}_2|\sin(\theta_1 - \theta_2)}{X}$$

$$= \frac{1 \times 1}{0.5}\sin(\theta_1 - \theta_2) \qquad |\boldsymbol{V}_1| = |\boldsymbol{V}_2| = 1\text{ pu}, \quad X = 0.5\text{ pu}$$

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$$0.5 = \sin(\theta_1 - \theta_2)$$
$$\theta_1 - \theta_2 = 30^\circ$$
$$\theta_2 = \theta_1 - 30^\circ = -30^\circ \qquad (\theta_1 = 0^\circ)$$

So, $\boldsymbol{V}_1 = 1\angle 0^\circ$ V

$$\boldsymbol{V}_2 = 1\angle -30^\circ \text{ V}$$

Current, $\boldsymbol{I}_{12} = \dfrac{\boldsymbol{V}_1 - \boldsymbol{V}_2}{Z} = \dfrac{1\angle 0^\circ - 1\angle 30^\circ}{j0.5} = (1 - j0.288)$ pu

Current in $\boldsymbol{S}_{D_2}$ is $\boldsymbol{I}_2$, $\boldsymbol{S}_{D_2} = \boldsymbol{V}_2 \boldsymbol{I}_2^*$

$$1 = 1\angle -30^\circ \boldsymbol{I}_2^*$$
$$\boldsymbol{I}_2 = 1\angle -30^\circ \text{ pu}$$

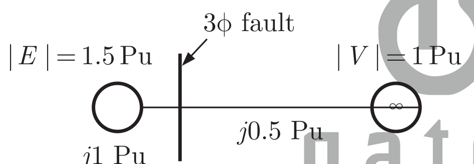
Current in $\boldsymbol{Q}_{G_2}$, $\boldsymbol{I}_G = \boldsymbol{I}_2 - \boldsymbol{I}_{12} = 1\angle -30^\circ - (1 - j0.288)$

$$= 0.268\angle -120^\circ$$

VAR rating of capacitor,

$$Q_C = |\boldsymbol{V}_2||\boldsymbol{V}_G| = 1 \times 0.268 = 0.268 \text{ pu}$$

SOL 5.6 Option (D) is correct.



Total reactance, $X = j1 + j0.5 = j1.5$ pu

Critical angle is given as,

$$\delta_{cr} = \cos^{-1}[(\pi - 2\delta_0)\sin\delta_0 - \cos\delta_0] \qquad \text{...(i)}$$

$\delta_0 \rightarrow$ steady state torque angle.

Steady state power is given as

$$P_m = P_{\max}\sin\delta_0$$

where, $P_{\max} = \dfrac{|E||V|}{|X|}$

So, $P_m = \dfrac{|E||V|}{|X|}\sin\delta_0$

$$0.5 = \frac{(1.5)(1)}{1.5}\sin\delta_0 \qquad P_m = 0.5 \text{ pu}$$

$$\sin\delta_0 = 0.5$$
$$\delta_0 = 30^\circ$$

In radian, $\delta_0 = 30^\circ \times \dfrac{\pi}{180^\circ} = 0.523$

Substituting δ_0 into equation (i)

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$$\delta_{cr} = \cos^{-1}[(\pi - 2 \times 0.523)\sin 30^\circ - \cos 30^\circ]$$
$$= \cos^{-1}[(2.095)(0.5) - 0.866]$$
$$= \cos^{-1}(0.1815) \simeq 79.6^\circ$$

SOL 5.7 Option ( ) is correct

SOL 5.8 Option (A) is correct.

Negative phase sequence relay is used for the protection of alternators against unbalanced loading that may arise due to phase-to-phase faults.

SOL 5.9 Option (C) is correct.

Steady state stability or power transfer capability

$$P_{\max} = \frac{|E||V|}{X}$$

To improve steady state limit, reactance X should be reduced. The stability may be increased by using two parallel lines. Series capacitor can also be used to get a better regulation and to increase the stability limit by decreasing reactance.

Hence (C) is correct option.

SOL 5.10 Option (A) is correct.

We know that

$$loss \propto P_G^2$$
$$loss \propto \text{length}$$

Distance of load from G_1 is 25 km Distance of load from G_2 & G_3 is 75 km generally we supply load from nearest generator. So maximum of load should be supplied from G_1. But G_2 & G_3 should be operated at same minimum generation.

SOL 5.11 Option (B) is correct.

Power angle for salient pole alternator is given by

$$\tan\delta = \frac{V_t \sin\phi + I_a X_q}{V_t \cos\phi + I_a R_a}$$

Since the alternator is delivering at rated kVA rated voltage

$$I_a = 1 \text{ pu}$$
$$V_t = 1 \text{ pu}$$
$$\phi = 0^\circ$$
$$\sin\phi = 0, \quad \cos\phi = 1$$
$$X_q = 1 \text{ pu}, \quad X_d = 1.2 \text{ pu}$$
$$\tan\delta = \frac{1 \times 0 + 1(1)}{1 + 0}$$

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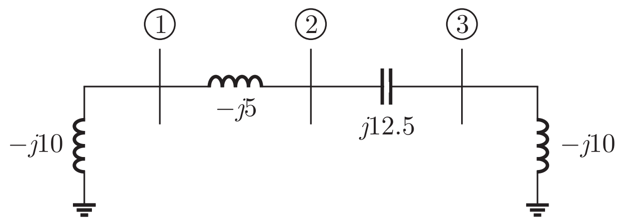
$$= 1$$
$$\delta = 45^\circ$$

SOL 5.12 Option (B) is correct.

The admittance diagram is shown below



here

$$y_{10} = -10j,\quad y_{12} = -5j,\quad y_{23} = 12.5j,\quad y_{30} = -10j$$

Note: y_{23} is taken positive because it is capacitive.

$$Y_{11} = y_{10} + y_{12} = -10j - 5j = -15j$$
$$Y_{12} = Y_{21} = -y_{21} = 5j$$
$$Y_{13} = Y_{31} = -y_{13} = 0$$
$$Y_{22} = y_{20} + y_{21} + y_{23} = 0 + (-5j) + (12.5j) = 7.5j$$
$$Y_{23} = Y_{32} = -y_{23} = -12.5j$$
$$Y_{33} = y_{30} + y_{13} + y_{23} = -10j + 0 + 12.5j = 2.5j$$

So the admittance matrix is

$$Y = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{33} \\ Y_{31} & Y_{32} & Y_{33} \end{bmatrix} = \begin{bmatrix} -15j & 5j & 0 \\ 5j & 7.5j & -12.5j \\ 0 & -12.5j & 2.5j \end{bmatrix}$$

SOL 5.13 Option (A) is correct.

For generator G_1

$$X''_{G_1} = 0.25 \times \frac{100}{250} = 0.1\text{ pu}$$

For generator G_2

$$X''_{G_1} = 0.10 \times \frac{100}{100} = 0.1\text{ pu}$$

$$X_{L_2} = X_{L_1} = 0.225 \times 10 = 2.25\,\Omega$$

For transmission lines L_1 and L_2

$$Z_{\text{base}} = \frac{kV_{\text{base}}^2}{MVA_{\text{base}}} = \frac{15 \times 15}{100} = 2.25\,\Omega$$

$$X''_{L_2}(\text{pu}) = \frac{2.25}{2.25} = 1\text{ pu}$$

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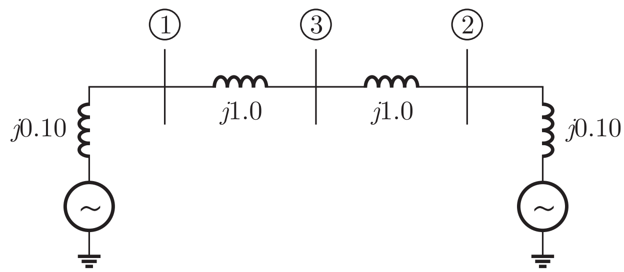
$$X''_{L_1}(\text{pu}) = \frac{2.25}{2.25} = 1 \text{ pu}$$

So the equivalent pu reactance diagram



SOL 5.14 Option (D) is correct.

We can see that at the bus 3, equivalent thevenin's impedance is given by

$$X_{th} = (j0.1 + j1.0)\,||\,(j0.1 + j1.0) = j1.1\,||\,j1.1 = j0.55 \text{ pu}$$

$$\text{Fault MVA} = \frac{\text{Base MVA}}{X_{th}} = \frac{100}{0.55} = 181.82 \text{ MVA}$$

SOL 5.15 Option (C) is correct.

Given that,

$$I > 0$$

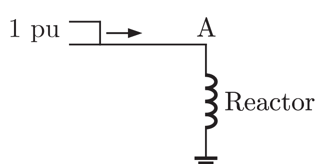
$\because$ $V_{AB} > 0$ since it is Rectifier O/P

$V_{CD} > 0$ since it is Inverter I/P

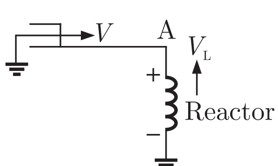
$\because$ $I > 0$ so $V_{AB} > V_{CD}$, Than current will flow in given direction.

SOL 5.16 Option (A) is correct.

Given step voltage travel along lossless transmission line.



$\because$ Voltage wave terminated at reactor as.



By Applying KVL

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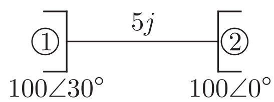
$$V + V_L = 0$$
$$V_L = -V$$
$$V_L = -1 \text{ pu}$$

SOL 5.17 Option (A) is correct.

Given two buses connected by an Impedance of $(0 + j5)\,\Omega$

The Bus '1' voltage is $100\angle 30°$ V and Bus '2' voltage is $100\angle 0°$ V

We have to calculate real and reactive power supply by bus '1'



$$P + jQ = VI^* = 100\angle 30°\left[\frac{100\angle 30° - 100\angle 0°}{5j}\right]$$
$$= 100\angle 30°\,[20\angle -60° - 20\angle -90°]$$
$$= 2000\angle -30° - 2000\angle -60°$$
$$P + jQ = 1035\angle 15°$$

real power $\quad P = 1035\cos 15° = 1000$ W

reactive power $\quad Q = 1035\sin 15° = 268$ VAR

SOL 5.18 Option (C) is correct.

Given 3-ϕ, 33 kV oil circuit breaker.

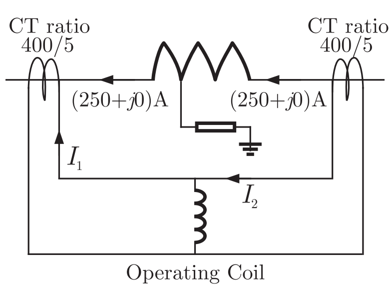
Rating 1200 A, 2000 MVA, 3 sec

Symmetrical breaking current $I_b = ?$

$$I_b = \frac{MVA}{\sqrt{3}\ \text{kV}}\ \text{kA} = \frac{2000}{\sqrt{3} \times 33} = 34.99\ \text{kA} \simeq 35\ \text{kA}$$

SOL 5.19 Option (C) is correct.

Given a stator winding of an alternator with high internal resistance fault as shown in figure



Current through operating coil

$$I_1 = 220 \times \frac{5}{400}\ \text{A},\ I_2 = 250 \times \frac{5}{400}\ \text{A}$$

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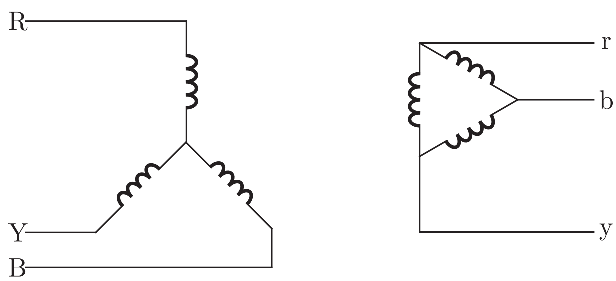
Operating coil current $= I_2 - I_1 = (250 - 220) \times 5/400 = 0.375$ Amp

SOL 5.20 Option (C) is correct.

Zero sequence circuit of 3-ϕ transformer shown in figure is as following:



No option seems to be appropriate but (C) is the nearest.

SOL 5.21 Option (D) is correct.

Given that

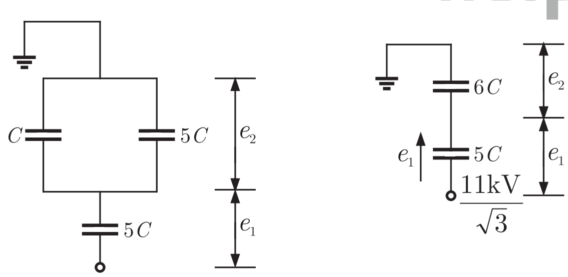
A 50 Hz Generator is initially connected to a long lossless transmission line which is open circuited as receiving end as shown in figure.

Due to ferranti effect the magnitude of terminal voltage does not change, and the field current decreases.

SOL 5.22 Option (B) is correct.

Given : 3-ϕ, 50 Hz, 11 kV distribution system, We have to find out $e_1, e_2 = ?$

Equivalent circuit is as following



$$e_1 = \frac{\frac{11}{\sqrt{3}}(6C)}{6C + 5C} = \frac{11}{\sqrt{3}} \times \frac{6}{11} = 3.46 \text{ kV}$$

$$e_2 = \frac{11}{\sqrt{3}} \times \frac{5}{11} = 2.89 \text{ kV}$$

SOL 5.23 Option (A) is correct.

Given : 3-ϕ, 50 Hz, 11 kV cable

$$C_1 = 0.2\,\mu\text{F}$$

$$C_2 = 0.4\,\mu\text{F}$$

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Charging current I_C per phase = ?

$$\text{Capacitance Per Phase } C = 3C_1 + C_2$$

$$C = 3 \times 0.2 + 0.4 = 1\,\mu\text{F}$$

$$\omega = 2\pi f = 314$$

$$\text{Changing current } I_C = \frac{V}{X_C} = V(\omega C) = \frac{11 \times 10^3}{\sqrt{3}} \times 314 \times 1 \times 10^{-6}$$

$$= 2 \text{ Amp}$$

SOL 5.24 Option (B) is correct.

Generator G_1 and G_2

$$X_{G1} = X_{G2} = X_{\text{old}} \times \frac{\text{New MVA}}{\text{Old MVA}} \times \left(\frac{\text{Old kV}}{\text{New kV}}\right)^2$$

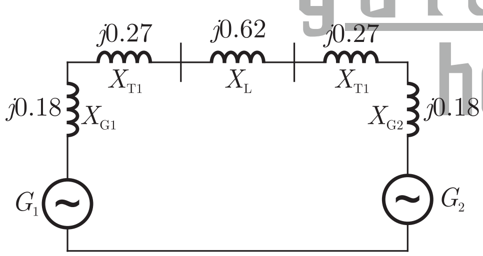
$$= j0.9 \times \frac{200}{100} \times \left(\frac{25}{25}\right)^2 = j0.18$$

$$\text{Same as } X_{T1} = j0.12 \times \frac{200}{90} \times \left(\frac{25}{25}\right)^2 = j0.27$$

$$X_{T2} = j0.12 \times \frac{200}{90} \times \left(\frac{25}{25}\right)^2 = j0.27$$

$$X_{\text{Line}} = 150 \times \frac{220}{(220)^2} = j0.62$$

The Impedance diagram is being given by as



SOL 5.25 Option ( ) is correct.

SOL 5.26 Option (C) is correct.

We know complex power

$$S = P + jQ = VI(\cos\phi + j\sin\phi) = VIe^{j\phi}$$

$$I = \frac{S}{Ve^{j\phi}}$$

$\because$ Real Power loss $= I^2R$

$$P_L = \left(\frac{S}{Ve^{j\phi}}\right)^2 R = \frac{S^2R}{e^{j2\phi}} \times \frac{1}{V^2} \qquad \because \frac{S^2R}{e^{j2\phi}} = \text{Constant}$$

So $$P_L \propto \frac{1}{V^2}$$

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SOL 5.27 Option (C) is correct.

Y_{Bus} matrix of Y-Bus system are given as

$$Y_{Bus} = j\begin{bmatrix} -5 & 2 & 2.5 & 0 \\ 2 & -10 & 2.5 & 0 \\ 2.5 & 2.5 & -9 & 4 \\ 0 & 4 & 4 & -8 \end{bmatrix}$$

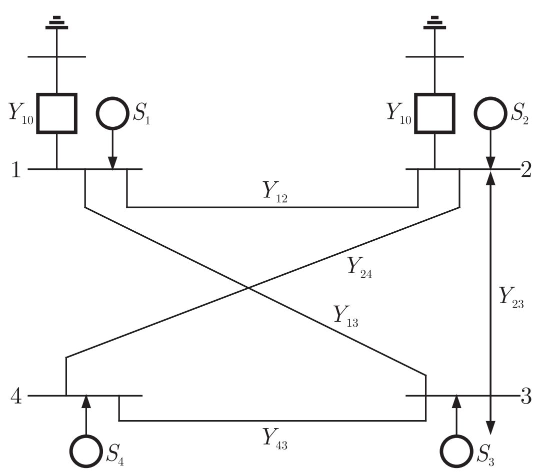
We have to find out the buses having shunt element

We know $$Y_{Bus} = \begin{bmatrix} y_{11} & y_{12} & y_{13} & y_{14} \\ y_{21} & y_{22} & y_{23} & y_{24} \\ y_{31} & y_{32} & y_{33} & y_{34} \\ y_{41} & y_{42} & y_{43} & y_{44} \end{bmatrix}$$

Here
$$y_{11} = y_{10} + y_{12} + y_{13} + y_{14} = -5j$$
$$y_{22} = y_{20} + y_{21} + y_{23} + y_{24} = -10j$$
$$y_{33} = y_{30} + y_{31} + y_{32} + y_{34} = -9j$$
$$y_{44} = y_{40} + y_{41} + y_{42} + y_{43} = -8j$$
$$y_{12} = y_{21} = -y_{12} = 2j$$
$$y_{13} = y_{31} = -y_{13} = 2.5j$$
$$y_{14} = y_{41} = -y_{14} = 0j$$
$$y_{23} = y_{32} = -y_{23} = 2.5j$$
$$y_{24} = y_{42} = -y_{24} = 4j$$

So
$$y_{10} = y_{11} - y_{12} - y_{13} - y_{14} = -5j + 2j + 2.5j + 0j = -0.5j$$
$$y_{20} = y_{22} - y_{12} - y_{23} - y_{24} = -10j + 2j + 2.5j + 4j = -1.5j$$
$$y_{30} = y_{33} - y_{31} - y_{32} - y_{34} = -9j + 2.5j + 2.5j + 4j = 0$$
$$y_{40} = y_{44} - y_{41} - y_{42} - y_{43} = -8j - 0 + 4j + 4j = 0$$

Admittance diagram is being made by as



From figure. it is cleared that branch (1) & (2) behaves like shunt element.

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SOL 5.28 Option (B) is correct.

We know that

- Shunt Capacitors are used for improving power factor.
- Series Reactors are used to reduce the current ripples.
- For increasing the power flow in line we use series capacitor.
- Shunt reactors are used to reduce the Ferranti effect.

SOL 5.29 Option (C) is correct.

We know that for different type of transmission line different type of distance relays are used which are as follows.

Short Transmission line -Ohm reactance used

Medium Transmission Line -Reactance relay is used

Long Transmission line -Mho relay is used

SOL 5.30 Option (C) is correct.

Given that three generators are feeding a load of 100 MW. For increased load power demand, Generator having better regulation share More power, so Generator -1 will share More power than Generator -2.

SOL 5.31 Option (A) is correct.

Given Synchronous generator of 500 MW, 21 kV, 50 Hz, 3-ϕ, 2-pole

P.F $= 0.9$, Moment of inertia $M = 27.5 \times 10^3$ kg-m^2

Inertia constant $H = ?$

Generator rating in MVA $G = \dfrac{P}{\cos\phi} = \dfrac{500\text{ MW}}{0.9} = 555.56\text{ MVA}$

$$N = \frac{120 \times f}{\text{pole}} = \frac{120 \times 50}{2} = 3000 \text{ rpm}$$

$$\text{Stored K.E} = \frac{1}{2}M\omega^2 = \frac{1}{2}M\left(\frac{2\pi N}{60}\right)^2$$

$$= \frac{1}{2} \times 27.5 \times 10^3 \times \left(\frac{2\pi \times 3000}{60}\right)\text{MJ}$$

$$= 1357.07\text{ MJ}$$

$$\text{Inertia constant } (H) = \frac{\text{Stored K.E}}{\text{Rating of Generator (MVA)}}$$

$$H = \frac{1357.07}{555.56}$$

$$= 2.44\text{ sec}$$

SOL 5.32 Option (D) is correct.

Given for X to F section of phase 'a'

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V_a-Phase voltage and I_a-phase current.
Impedance measured by ground distance,

$$\text{Relay at X} = \frac{\text{Bus voltage}}{\text{Current from phase 'a'}} = \frac{V_a}{I_a}\,\Omega$$

SOL 5.33 Option (D) is correct.
For EHV line given data is
Length of line $= 300$ km and $\beta = 0.00127\text{S rad/km}$

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

So $$\frac{l}{\lambda}\% = \frac{300}{4947.39} \times 100 = 0.06063 \times 100$$

$$\frac{l}{\lambda}\% = 6.063$$

SOL 5.34 Option (B) is correct.
For three phase transmission line by solving the given equation

We get, $$\begin{bmatrix} \Delta V_a \\ \Delta V_b \\ \Delta V_c \end{bmatrix} = \begin{bmatrix} (X_s - X_m) & 0 & 0 \\ 0 & (X_s - X_m) & 0 \\ 0 & 0 & (X_s + 2X_m) \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

Zero sequence Impedance $= X_s + 2X_m = 48$ ...(1)

and Positive Sequence Impedance $=$ Negative Sequence Impedance

$= (X_s - X_m)$

$= 15$ ...(2)

By solving equation (1) and (2)

$$Z_s \text{ or } X_s = 26 \text{ and } Z_m \text{ or } X_m = 11$$

SOL 5.35 Option ( ) is correct.

SOL 5.36 Option (B) is correct.
SIL has no effect of compensation
So SIL $= 2280$ MW

SOL 5.37 Option (C) is correct.

Given $P_{G1} + P_{G2} = 250$ MW ...(1)

and $$\left.\begin{aligned} C_1(P_{G1}) &= P_{G1} + 0.055P_{G1}^2 \\ C_2(P_{G2}) &= 3P_{G2} + 0.03P_{G2}^2 \end{aligned}\right\}$$ ...(2)

from equation (2)

$$\frac{dC_1}{dP_{G1}} = 1 + 0.11P_{G1}$$ ...(3a)

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and $\frac{dC_2}{dP_{G2}} = 3 + 0.06P_{G2}$ ...(3b)

Since the system is loss-less

Therefore $\frac{dC_1}{dP_{G1}} = \frac{dC_2}{dP_{G2}}$

So from equations (3a) and (3b)

We have $0.11P_{G1} - 0.06P_{G2} = 2$ ...(4)

Now solving equation (1) and (4), we get

$$P_{G1} = 100 \text{ MW}$$

$$P_{G2} = 150 \text{ MW}$$

SOL 5.38 Option (B) is correct.

After connecting both the generators in parallel and scheduled to supply 0.5 Pu of power results the increase in the current.

$\therefore$ Critical clearing time will reduced from 0.28 s but will not be less than 0.14 s for transient stability purpose.

SOL 5.39 Option (D) is correct.

Given that the each section has equal impedance.

Let it be R or Z, then by using the formula

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

$$\text{On removing } (e_1);\ \text{losses} = (1)^2 R + (1+2)^2 R + (1+2+5)^2 R$$

$$= R + 9R + 64R = 74R$$

Similarly,

$$\text{On removing } e_2;\text{losses} = 5^2 R + (5+2)^2 R + (5+2+1)^2 R = 138R$$

$$\text{lossess on removing } e_3 = (1)^2 R + (2)^2 R + (5+2)^2 R$$

$$= 1R + 4R + 49R = 54R$$

$$\text{on removing } e_4 \text{ lossless} = (2)^2 R + (2+1)^2 R + 5^2 R$$

$$= 4R + 9R + 25R = 38R$$

So, minimum losses are gained by removing e_4 branch.

SOL 5.40 Option (A) is correct.

Given : $V(t) = V_m \cos(\omega t)$

For symmetrical $3-\phi$ fault, current after the fault

$$i(t) = Ae^{-(R/L)t} + \frac{\sqrt{2}\,V_m}{|Z|}\cos(\omega t - \alpha)$$

At the instant of fault i.e $t = t_0$, the total current $i(t) = 0$

$$\therefore \quad 0 = Ae^{-(R/L)t_0} + \frac{\sqrt{2}\,V_m}{|Z|}\cos(\omega t_0 - \alpha)$$

$$Ae^{-(R/L)t_0} = -\frac{\sqrt{2}V_m}{|Z|}\cos(\omega t_0 - \alpha)$$

Maximum value of the dc offset current

$$Ae^{-(R/L)t_0} = -\frac{\sqrt{2}V_m}{|Z|}\cos(\omega t_0 - \alpha)$$

For this to be negative max.

$$(\omega t_0 - \alpha) = 0$$

or $$t_0 = \frac{\alpha}{\omega} \qquad ...(1)$$

and $$Z = 0.004 + j0.04$$

$$Z = |Z|\angle\alpha = 0.0401995\angle 84.29^\circ$$

$$\alpha = 84.29^\circ \text{or } 1.471 \text{ rad.}$$

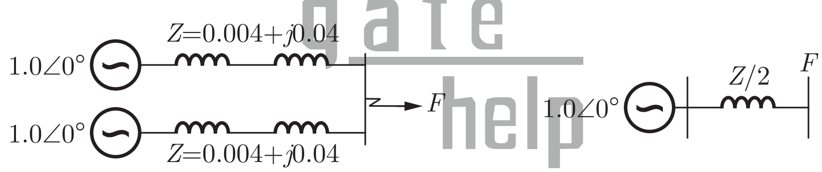
From equation (1)

$$t_0 = \frac{1.471}{(2\pi \times 50)} = 0.00468 \text{ sec}$$

$$t_0 = 4.682 \text{ ms}$$

SOL 5.41 Option (C) is correct.

Since the fault 'F' is at mid point of the system, therefore impedance seen is same from both sides.



$$\frac{Z}{2} = 0.0201\angle 84.29^\circ$$

$$Z_1(\text{Positive sequence}) = \frac{Z}{2} = 0.0201\angle 84.29^\circ$$

also $Z_1 = Z_2 = Z_0$ (for 3-ϕ fault)

$\therefore$ $$I_f(\text{pu}) = \frac{1\angle 0^\circ}{Z_1} = \frac{1\angle 0^\circ}{0.0201\angle 84.29^\circ}$$

So magnitude $$|I_f|_{(\text{p.u.})} = 49.8$$

$\therefore$ Fault current $$I_f = 49.8 \times \frac{100}{\sqrt{3} \times 400} = 7.18 \text{ kA}$$

SOL 5.42 Option (A) is correct.

If fault is LG in phase 'a'

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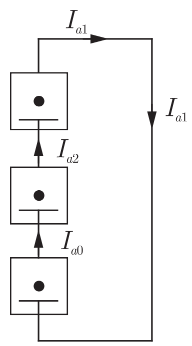


$$Z_1 = \frac{Z}{2} = 0.0201\angle 84.29^\circ$$

$$Z_2 = Z_1 = 0.0201\angle 84.29^\circ$$

and $$Z_0 = 3Z_1 = 0.0603\angle 84.29^\circ$$

Then $$I_a/3 = I_{a1} = I_{a2} = I_{a0}$$

$$I_{a1}(pu) = \frac{1.0\angle 0^\circ}{Z_1 + Z_2 + Z_0}$$

and $$|I_{a1}| = \frac{1.0}{(0.0201 + 0.0201 + 0.0603)} = 9.95 \text{ pu}$$

Fault Current $$I_f = I_a = 3I_{a1} = 29.85 \text{ pu}$$

So Fault current $$I_f = 29.85 \times \frac{100}{\sqrt{3} \times 400} = 4.97 \text{ kA}$$

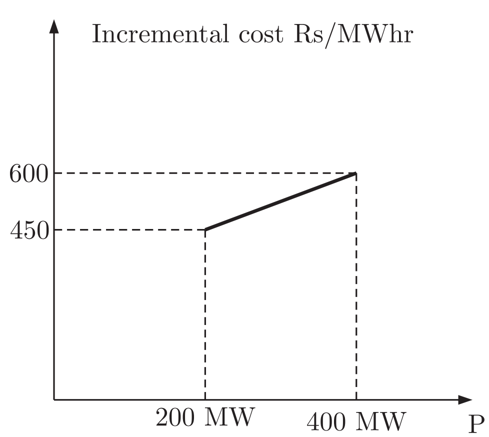
SOL 5.43 Option (A) is correct.

$\because$ Equal Phase shift of point A & B with respect to source from both bus paths.

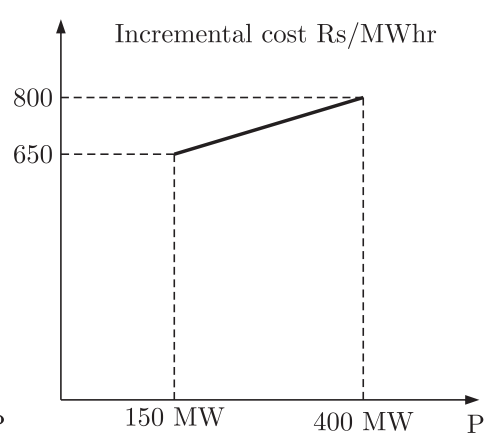
So the type of transformer Y-Y with angle 0°.

SOL 5.44 Option (C) is correct.

Given incremental cost curve



Generator A



Generator B

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$$P_A + P_B = 700 \text{ MW}$$

For optimum generator $P_A = ?,\ P_B = ?$
From curve, maximum incremental cost for generator A

$$= 600 \text{ at } 450 \text{ MW}$$

and maximum incremental cost for generator B

$$= 800 \text{ at } 400 \text{ MW}$$

minimum incremental cost for generator B

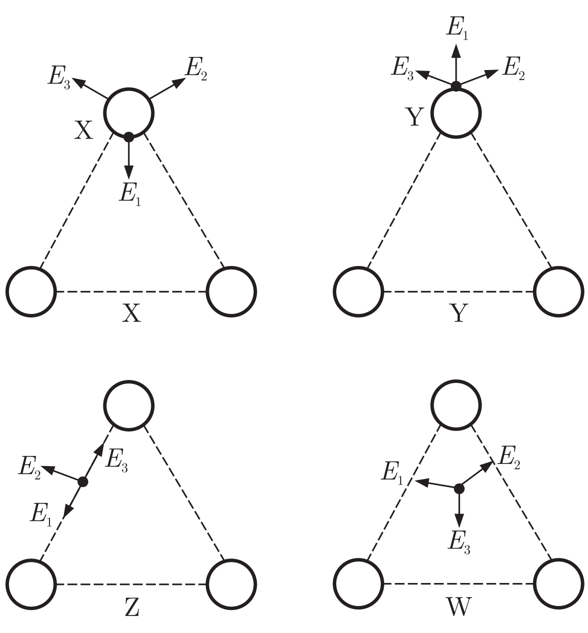
$$= 650 \text{ at } 150 \text{ MW}$$

Maximim incremental cost of generation A is less than the minimum incremental constant of generator B. So generator A operate at its maximum load = 450 MW for optimum generation.

$$P_A = 450 \text{ MW}$$
$$P_B = (700 - 450)$$
$$= 250 \text{ MW}$$

SOL 5.45 Option (C) is correct.
Here power sharing between the AC line and HVDC link can be changed by controlling the HVDC converter alone because before changing only grid angle we can change the power sharing between the AC line and HVDC link.

SOL 5.46 Option (B) is correct.
We have to find out maximum electric field intensity at various points. Electric field intensity is being given by as follows



From figures it is cleared that at point Y there is minimum chances of

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cancelation. So maximum electric field intensity is at point Y.

SOL 5.47 Option (D) is correct.
To increase capacitive dc voltage slowly to a new steady state value first we have to make $\delta = -$ ve than we have to reach its original value.

SOL 5.48 Option (B) is correct.
Given that

Reactance of line $= 0.045$ pu $\Rightarrow L = \dfrac{.045}{2\pi \times 50}$

Suspectance of Line $= 1.2$ pu $\Rightarrow C = \dfrac{1}{2\pi \times 50} \times \dfrac{1}{1.2}$

Velocity of wave propagation $= 3 \times 10^5$ Km/sec

Length of line $l = ?$

We know velocity of wave propagation

$$V_X = \frac{l}{\sqrt{LC}}$$

$$l = V_X\sqrt{LC} = 3 \times 10^5 \sqrt{\frac{.45}{2\pi \times 50} \times \frac{1}{2\pi \times 50} \times \frac{1}{1.2}}$$

$$= 185 \text{ Km}$$

SOL 5.49 Option (C) is correct.
Due to the fault 'F' at the mid point and the failure of circuit-breaker '4' the sequence of circuit-breaker operation will be
5, 6, 7, 3, 1, 2 (as given in options)
(due to the fault in the particular zone, relay of that particular zone must operate first to break the circuit, then the back-up protection applied if any failure occurs.)

SOL 5.50 Option (A) is correct.

$$R = [V_{an}\ V_{bn}\ V_{cn}]\begin{bmatrix} 0 & \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{3}} \\ -\frac{1}{\sqrt{3}} & 0 & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{3}} & 0 \end{bmatrix}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

By solving we get

$$R = \left[\frac{V_{an}}{\sqrt{3}}(i_b - i_c) + \frac{V_{bn}}{\sqrt{3}}(i_c - i_a) + \frac{V_c}{\sqrt{3}}(i_a - i_b)\right]$$

$$R = 3(VI)\ ,\ \text{where } \frac{(i_b - i_c)}{\sqrt{3}} = I \text{ and } V_{an} = V$$

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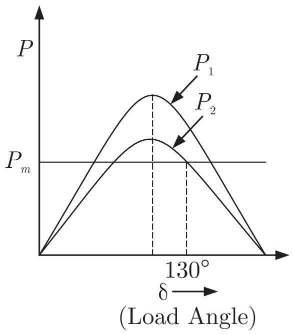
SOL 5.51 Option (C) is correct.



Here $P_1 \rightarrow$ power before the tripping of one ckt

$P_2 \rightarrow$ Power after tripping of one ckt

$$P = \frac{EV}{X}\sin\delta$$

Since $$P_{max} = \frac{EV}{X}$$

$\therefore$ $$P_{2max} = \frac{EX}{X_2}, \qquad \text{here, } [X_2 = (0.1 + X)\,(\text{pu})]$$

To find maximum value of X for which system does not loose synchronism

$$P_2 = P_m \text{ (shown in above figure)}$$

$\therefore$ $$\frac{EV}{X_2}\sin\delta_2 = P_m$$

as $P_m = 1$ pu, $E = 1.0$ pu, $V = 1.0$ pu

$$\frac{1.0 \times 1.0}{X_2}\sin 130^\circ = 1$$

$\Rightarrow$ $$X_2 = 0.77$$

$\Rightarrow$ $$(0.1 + X) = 0.77$$

$\Rightarrow$ $$X = 0.67$$

SOL 5.52 Option (B) is correct.

Given that

$$F_P = KAF_S \qquad ...(1)$$

where, Phase component $F_P = \begin{bmatrix} f_a \\ f_b \\ f_c \end{bmatrix}$, sequence component $F_S = \begin{bmatrix} f_p \\ f_n \\ f_o \end{bmatrix}$

and $$A = \begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix}$$

$\therefore$ $$\left.\begin{aligned} V_P &= KA\,V_S \\ I_P &= KAI_S \end{aligned}\right\} \qquad ...(2)$$

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and $$V_S = Z'[I_S] \qquad ...(3)$$

where $$Z' = \begin{bmatrix} 0.5 & 0 & 0 \\ 0 & 0.5 & 0 \\ 0 & 0 & 2.0 \end{bmatrix}$$

We have to find out Z if $V_P = ZI_P$ ...(4)

From equation (2) and (3)

$$V_P = KAZ'[I_S]$$

$$V_P = KAZ'\left(\frac{A^{-1}}{K}\right)I_p$$

$$V_P = AZ'A^{-1}I_p \qquad ...(5)$$

$$A = \begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix}$$

$$A^{-1} = \frac{\text{Adj}\,A}{|A|}$$

$$\text{Adj}\,A = \begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix}$$

$$|A| = \frac{1}{3}$$

$$A^{-1} = \frac{1}{3}\begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix}$$

From equation (5)

$$V_p = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix}\begin{bmatrix} 0.5 & 0 & 0 \\ 0 & 0.5 & 0 \\ 0 & 0 & 2 \end{bmatrix}\begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix}I_p = \begin{bmatrix} 1 & 0.5 & 0.5 \\ 0.5 & 1 & 0.5 \\ 0.5 & 0.5 & 1 \end{bmatrix}I_p \qquad ...(6)$$

Comparing of equation (5) and (6)

$$Z = \begin{bmatrix} 1 & 0.5 & 0.5 \\ 0.5 & 1 & 0.5 \\ 0.5 & 0.5 & 1 \end{bmatrix}$$

SOL 5.53 Option (A) is correct.

Given that the first two power system are not connected and separately loaded.

Now these are connected by short transmission line.

as $P_1 = P_2 = Q_1 = Q_2 = 0$

So here no energy transfer. The bus bar voltage and phase angle of each system should be same than angle difference is

$$\theta = 30^\circ - 20^\circ$$

$= 10^\circ$

SOL 5.54 Option (B) is correct.

Given that,

230 V, 50 Hz, 3-ϕ, 4-wire system

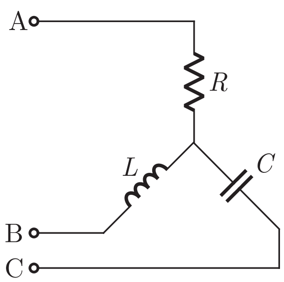
$P = \text{Load} = 4\text{ kw}$ at unity Power factor

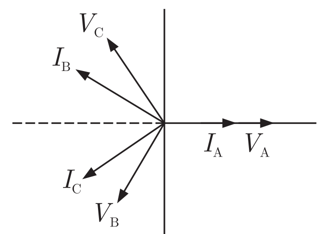
$I_N = 0$ through the use of pure inductor and capacitor

Than $\quad L = ?,\ C = ?$

$\because \quad I_N = 0 = I_A + I_B + I_C \quad \ldots(1)$

Network and its Phasor is being as





Here the inductor is in phase B and capacitor is in Phase C.

We know $\quad P = VI$

So $\quad I_a = \frac{P}{V} = \frac{4 \times 10^3}{230} = 17.39\text{ Amp.}$

From equation (1)

$$\overline{I_A} = -(\overline{I_B} + \overline{I_C}) \qquad \because I_b \simeq I_c$$

$$\therefore \quad I_A = -\left(I_B \times \frac{\sqrt{3}}{2} + I_C \times \frac{\sqrt{3}}{2}\right)$$

$$\therefore \quad I_A = \sqrt{3}\,I_B = \sqrt{3}\,I_C$$

$$I_B \simeq I_C = \frac{17.39}{\sqrt{3}} \simeq 10\text{ Amp}$$

Now $\quad X_C = \frac{V}{I_C} = \frac{230}{10} \simeq 23\,\Omega$

and $\quad X_C = \frac{1}{2\pi f C}$

$$\Rightarrow \quad C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi \times 50 \times 23} = 139.02\,\mu\text{F}$$

$$X_L = \frac{V}{I_L} = \frac{230}{10} \simeq 23\,\Omega = 2\pi f L$$

$$\Rightarrow \quad L = \frac{X_L}{2\pi f} = \frac{23}{2\pi \times 100} = 72.95\text{ mH}$$

So $\quad L = 72.95$ mH in phase B

$\quad C = 139.02\ \mu$F in phase C

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SOL 5.55 Option (A) is correct.

Maximum continuous power limit of its prime mover with speed governor of 5% droop.

Generator feeded to three loads of 4 MW each at 50 Hz.

Now one load Permanently tripped

$$\therefore \quad f = 48 \text{ Hz}$$

If additional load of 3.5 MW is connected than $f = ?$

$\because$ Change in Frequency w.r.t to power is given as

$$\Delta f = \frac{\text{drop out frequency}}{\text{rated power}} \times \text{Change in power}$$

$$= \frac{5}{15} \times 3.5 = 1.16\% = 1.16 \times \frac{50}{100} = 0.58 \text{ Hz}$$

System frequency is $= 50 - 0.58 = 49.42$ Hz

SOL 5.56 Option (B) is correct.

With the help of physical length of line, we can recognize line as short, medium and long line.

SOL 5.57 Option (A) is correct.

For capacitor bank switching vacuum circuit breaker is best suited in view of cost and effectiveness.

SOL 5.58 Option (B) is correct.

Ratio of operating coil current to restraining coil current is known as bias in biased differential relay.

SOL 5.59 Option (B) is correct.

HVDC links consist of rectifier, inverter, transmission lines etc, where rectifier consumes reactive power from connected AC system and the inverter supplies power to connected AC system.

SOL 5.60 Option (C) is correct.

Given $ABCD$ constant of 220 kV line

$A = D = 0.94\angle 10^\circ$, $B = 130\angle 730^\circ$, $C = 0.001\angle 900^\circ$, $V_S = 240$ kV

% voltage regulation is being given as

$$\%\text{V.R.} = \frac{(V_R)_{\text{No Load}} - (V_R)_{\text{Full load}}}{V_R(\text{Full load})} \times 100$$

At no load $I_R = 0$

$$(V_R)_{NL} = V_S/A,\ (V_R)_{\text{Full load}} = 220 \text{ kV}$$

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$$\%\text{V.R.} = \frac{\frac{240}{0.94} - 220}{220} \times 100$$

$$\%\text{V.R.} = 16$$

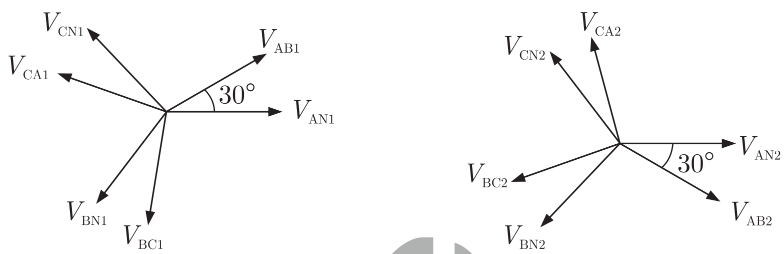
SOL 5.61 Option ( ) is correct.

SOL 5.62 Option (B) is correct.

Given that,

$V_{ab1} = X\angle\theta_1$, $V_{ab2} = Y\angle\theta_2$, Phase to neutral sequence volt= ?

First we draw phasor of positive sequence and negative sequence.



Positive sequence Negative sequence

From figure we conclude that positive sequence line voltage leads phase voltage by 30°

$$V_{AN1} = X\angle\theta_1 - 30°$$

$$V_{AN2} = 4\angle\theta_2 + 30°$$

SOL 5.63 Option (A) is correct.

For system base value 10 MVA, 69 kV, Load in pu(Z_{new}) = ?

$$Z_{\text{new}} = Z_{\text{old}} \times \frac{(\text{MVA})_{\text{old}}}{(\text{MVA})_{\text{new}}} \times \left(\frac{\text{kV}_{\text{new}}}{\text{kV}_{\text{old}}}\right)^2$$

$$Z_{\text{new}} = 0.72 \times \frac{20}{10} \times \left(\frac{69}{13.8}\right)^2 = 36 \text{ pu}$$

SOL 5.64 Option (A) is correct.

Unreliable convergence is the main disadvantage of gauss seidel load flow method.

SOL 5.65 Option (C) is correct.

Generator feeds power to infinite bus through double circuit line 3-ϕ fault at middle of line.

Infinite bus voltage(V) = 1 pu

Transient internal voltage of generator(E)= 1.1 pu

Equivalent transfer admittance during fault = 0.8 pu = $1/X$

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delivering power(P_S) = 1.0 pu

Perior to fault rotor Power angle $\delta = 30^\circ$, $f = 50$ Hz

Initial accelerating power(P_a)= ?

$$P_a = P_S - P_{m2}\sin\delta$$

$$= 1 - \frac{EV}{X}\sin 30^\circ = 1 - \frac{1.1\times 1}{1/0.8}\times\frac{1}{2} = 0.56 \text{ pu}$$

SOL 5.66 Option (B) is correct.

If initial acceleration power = X pu

Initial acceleration = ?

Inertia constant = ?

$$\alpha = \frac{P_a}{M} = \frac{X(\text{pu})\times \text{S}}{\text{SH/180F}} = \frac{180\times 50\times X\times S}{S\times S}$$

$$\alpha = 1800X \text{ deg/sec}^2$$

$$\text{Inertia const.} = \frac{1}{18} = 0.056$$

SOL 5.67 Option (D) is correct.

The post fault voltage at bus 1 and 3 are.

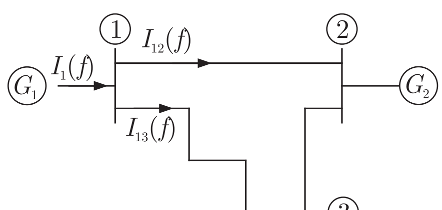
Pre fault voltage.

$$V_{Bus} = \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 1\angle 0^\circ \\ 1\angle 0^\circ \\ 1\angle 0^\circ \end{bmatrix}$$

At bus 2 solid fault occurs $Z(f) = 0$, $r = 2$

$$\text{Fault current } I_f = \frac{V_r^\circ}{Z_{rr}+Z_f} = \frac{V_2^\circ}{Z_{22}+Z_f}$$

$$Z_f = \frac{1\angle 0^\circ}{j0.24} = -4j$$



$$V_i(f) = V_i^\circ(0) - Z_{ir}I(f), \qquad V_i^\circ = \text{Prefault voltage}$$

$$V_1(f) = V_i^\circ - Z_{12}I_f = 1\angle 0^\circ - j0.08(-j4) = 1 - 0.32$$

$$V_1(f) = 0.68 \text{ pu}$$

$$V_3(f) = V_3^\circ - Z_{32}I_f = 1\angle 0^\circ - j0.16(-j4) = 1 - 0.64$$

$$V_3(f) = 0.36 \text{ pu}$$

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SOL 5.68 Option ( ) is correct.

SOL 5.69 Option (D) is correct.

Rating of Δ-connected capacitor bank for unity p.f.

real power $P_L = S\cos\phi = 12\sqrt{3} \times 0.8 = 16.627$ kW

reactive power $Q_L = S\sin\phi = 12\sqrt{3} \times 0.6 = 12.47$ kW

For setting of unity p.f. we have to set capacitor bank equal to reactive power $= 12.47$ kW

SOL 5.70 Option (D) is correct.

Given that pu parameters of 500 MVA machine are as following

$$M = 20 \text{ pu}, \; X = 2 \text{ pu}$$

Now value of M and X at 100 MVA base are

for inertia (M)

$$(\text{pu})_{\text{new}} = (\text{pu})_{\text{old}} \times \frac{\text{old MVA}}{\text{new MVA}}$$

$$(M_{\text{pu}})_{\text{new}} = (M_{\text{Pu}})_{\text{old}} \times \frac{500}{100} = 20 \times \frac{5}{1} = 100 \text{ pu}$$

and for reactance (X)

$$(\text{pu})_{\text{new}} = (\text{pu})_{\text{old}} \times \frac{\text{new MVA}}{\text{old MVA}}$$

$$(X_{\text{pu}})_{\text{new}} = (X_{\text{pu}})_{\text{old}} \times \frac{100}{500}$$

$$(X_{\text{Pu}})_{\text{new}} = 2 \times \frac{1}{5} = 0.4 \text{ pu}$$

SOL 5.71 Option (D) is correct.

800 kV has Power transfer capacity $= P$

At 400 kV Power transfer capacity = ?

We know Power transfer capacity

$$P = \frac{EV}{X}\sin\delta$$

$$P \propto V^2$$

So if V is half than Power transfer capacity is $\frac{1}{4}$ of previous value.

SOL 5.72 Option (B) is correct.

In EHV lines the insulation strength of line is governed by the switching over voltages.

SOL 5.73 Option (A) is correct.

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For bulk power transmission over very long distance HVDC transmission preferably used.

SOL 5.74 Option (D) is correct.

Parameters of transposed overhead transmission line

$$X_S = 0.4\,\Omega/\text{km},\ X_m = 0.1\,\Omega/\text{km}$$

$$+\text{ve sequence reactance } X_1 = ?$$

$$\text{Zero sequence reactance } X_0 = ?$$

We know for transposed overhead transmission line.

$$+\text{ve sequence component } X_1 = X_S - X_m = 0.4 - 0.1 = 0.3\,\Omega/\text{km}$$

$$\text{Zero sequence component } X_0 = X_S + 2X_m = 0.4 + 2(0.1) = 0.6\,\Omega/\text{km}$$

SOL 5.75 Option (C) is correct.

Industrial substation of 4 MW load $= P_L$

$$Q_C = 2\,\text{MVAR for load p.f.} = 0.97 \text{ lagging}$$

If capacitor goes out of service than load p.f. = ?

$$\cos\phi = 0.97$$

$$\tan\phi = \tan(\cos^{-1}0.97) = 0.25$$

$$\frac{Q_L - Q_C}{P_L} = 0.25$$

$$\frac{Q_L - 2}{4} = 0.25 \Rightarrow Q_L = 3\,\text{MVAR}$$

$$\phi = \tan^{-1}\left(\frac{Q_L}{P_L}\right) = \tan^{-1}\left(\frac{3}{4}\right) = 36^\circ$$

$$\cos\phi = \cos 36^\circ = 0.8 \text{ lagging}$$

SOL 5.76 Option (D) is correct.

$$Y_{22} = ?$$

$$I_1 = V_1 Y_{11} + (V_1 - V_2) Y_{12}$$

$$= 0.05 V_1 - j10(V_1 - V_2) = -j9.95 V_1 + j10 V_2$$

$$I_2 = (V_2 - V_1) Y_{21} + (V_2 - V_3) Y_{23}$$

$$= j10 V_1 - j9.9 V_2 - j0.1 V_3$$

$$Y_{22} = Y_{11} + Y_{23} + Y_2 = -j9.95 - j9.9 - 0.1j = -j19.95$$

SOL 5.77 Option (C) is correct.

$$F_1 = a + bP_1 + cP_1^2 \text{ Rs/hour}$$

$$F_2 = a + bP_2 + 2cP_2^2 \text{ Rs/hour}$$

For most economical operation

$$P_1 + P_2 = 300 \text{ MW then } P_1, P_2 = ?$$

We know for most economical operation

$$\frac{\partial F_1}{\partial P_1} = \frac{\partial F_2}{\partial P_2}$$

$$2cP_1 + b = 4cP_2 + b$$

$$P_1 = 2P_2 \quad ...(1)$$

$$P_1 + P_2 = 300 \quad ...(2)$$

from eq (1) and (2)

$$P_1 = 200\,\text{MW},\ P_2 = 100\,\text{MW}$$

SOL 5.78 Option (B) is correct.

We know that $ABCD$ parameters $\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ I_1 \end{bmatrix}$

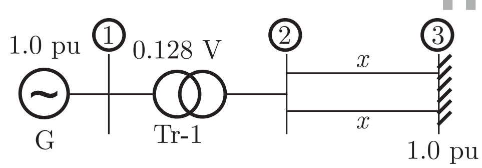
$$B = \left.\frac{V_1}{I_2}\right|_{V_2 = 0},\ C = \left.\frac{I_1}{V_2}\right|_{I_2 = 0}$$

In figure $\quad C = \dfrac{\dfrac{V_1}{Z_1 + Z_2}}{\dfrac{V_1}{Z_1 + Z_2} \times Z_2} = \dfrac{1}{Z_2}$

or $\quad Z_2 = \dfrac{1}{C} = \dfrac{1}{0.025\angle 45^\circ} = 40\angle - 45^\circ$

SOL 5.79 Option (D) is correct.

Given



Steady state stability Power Limit $= 6.25$ pu

If one of double circuit is tripped than

Steady state stability power limit $= ?$

$$P_{m1} = \frac{EV}{X} = \frac{1 \times 1}{0.12 + \frac{X}{2}} = 6.25$$

$$\frac{1}{0.12 + 0.5X} = 6.25$$

$\Rightarrow \quad X = 0.008$ pu

If one of double circuit tripped than

$$P_{m2} = \frac{EV}{X} = \frac{1 \times 1}{0.12 + X} = \frac{1}{0.12 + 0.08}$$

$$P_{m2} = \frac{1}{0.2} = 5 \text{ pu}$$

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SOL 5.80 Option (D) is correct.

Given data

$$\text{Substation Level} = 220 \text{ kV}$$

$$3\text{-}\phi \text{ fault level} = 4000 \text{ MVA}$$

$$\text{LG fault level} = 5000 \text{ MVA}$$

Positive sequence reactance:

$$\text{Fault current } I_f = \frac{4000}{\sqrt{3} \times 220}$$

$$X_1 = V_{ph}/I_f$$

$$= \frac{\frac{220}{\sqrt{3}}}{\frac{4000}{\sqrt{3} \times 220}} = \frac{220 \times 220}{4000} = 12.1\,\Omega$$

SOL 5.81 Option (B) is correct.

Zero sequence Reactance $X_0 = ?$

$$I_f = \frac{5000}{\sqrt{3} \times 220}$$

$$I_{a1} = I_{a2} = I_{a0} = \frac{I_f}{3} = \frac{5000}{3\sqrt{3} \times 220}$$

$$X_1 + X_2 + X_0 = \frac{V_{ph}}{I_{a1}} = \frac{\frac{220}{\sqrt{3}}}{\frac{5000}{220 \times 3\sqrt{3}}}$$

$$X_1 + X_2 + X_0 = \frac{220 \times 220}{3 \times 5000} = 29.04\,\Omega$$

$$X_1 = X_2 = 12.1\,\Omega$$

$$X_0 = 29.04 - 12.1 - 12.1 = 4.84\,\Omega$$

SOL 5.82 Option (B) is correct.

Instantaneous power supplied by 3-ϕ ac supply to a balanced R-L load.

$$P = V_a I_a + V_a I_b + V_c I_c$$

$$= (V_m \sin\omega t) I_m \sin(\omega t - \phi) + V_m \sin(\omega t - 120^\circ) I_m \sin(\omega t - 120^\circ - \phi)$$
$$+ V_m \sin(\omega t - 240^\circ) I_m \sin(\omega t - 240^\circ - \phi)$$

$$= VI[\cos\phi - \cos(2\omega t - \phi) + \cos\phi - \cos(2\omega t - 240 - \phi) + \cos\phi$$
$$- \cos(2\omega t + 240 - \phi)]$$

$$P = 3VI\cos\phi \qquad \text{...(1)}$$

equation (1) implies that total instantaneous power is being constant.

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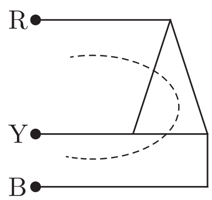
SOL 5.83 Option (C) is correct.

In 3-ϕ Power system, the rated voltage is being given by RMS value of line to line voltage.

SOL 5.84 Option (B) is correct.



In this figure the sequence is being given as RBY

SOL 5.85 Option (C) is correct.

In thermal power plants, the pressure in the working fluid cycle is developed by the help to feed water pump.

SOL 5.86 Option (A) is correct.

Kaplan turbines are used for harnessing low variable waterheads because of high percentage of reaction and runner adjustable vanes.

SOL 5.87 Option (B) is correct.

MHO relay is the type of distance relay which is used to transmission line protection. MHO Relay has the property of being inherently directional.

SOL 5.88 Option (C) is correct.

Surge impedance of line is being given by as

$$Z = \sqrt{\frac{L}{C}} = \sqrt{\frac{11 \times 10^{-3}}{11.68 \times 10^{-9}}} = 306.88\,\Omega$$

Ideal power transfer capability

$$P = \frac{V^2}{Z_0} = \frac{(800)^2}{306.88} = 2085 \text{ MW}$$

SOL 5.89 Option (D) is correct.

Given that,

$$\text{Power cable voltage} = 110 \text{ kV}$$

$$C = 125 \text{ nF/km}$$

$$\text{Dielectric loss tangent} = \tan\delta = 2 \times 10^{-4}$$

$$\text{Dielectric power loss} = ?$$

dielectric power loss is given by

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$$\begin{aligned} P &= 2V^2 \omega C \tan\delta \\ &= 2(110 \times 10^3)^2 \times 2\pi f \times 125 \times 10^{-9} \times 2 \times 10^{-4} \\ &= 2(121 \times 10^8 \times 2 \times 3.14 \times 50 \times 250 \times 10^{-13}) = 189 \text{ W/km} \end{aligned}$$

SOL 5.90 Option (A) is correct.

Given data

Lightening stroke discharge impulse current of $I = 10$ kA

Transmission line voltage = 400 kV

Impedance of line $Z = 250\,\Omega$

Magnitude of transient over-voltage = ?

The impulse current will be equally divided in both directions since there is equal distribution on both sides.

Then magnitude of transient over-voltage is

$$V = IZ/2 = \frac{10}{2} \times 10^3 \times 250$$

$$= 1250 \times 10^3 \text{ V} = 1250 \text{ kV}$$

SOL 5.91 Option (C) is correct.

The A, B, C, D parameters of line

$$A = D = 0.936\angle 0.98^\circ$$

$$B = 142\angle 76.4^\circ$$

$$C = (-5.18 + j914)10^{-6}\,\Omega$$

At receiving end $P_R = 50\,\text{MW}$, $V_R = 220$ kV

p.f $= 0.9$ lagging

$V_S = ?$

Power at receiving end is being given by as follows

$$P_R = \frac{|V_S||V_R|}{|B|}\cos(\beta - \delta) - \frac{|A||V_R|^2}{|B|}\cos(\beta - \alpha)$$

$$= \frac{|V_S| \times 220}{142}\cos(76.4^\circ - \delta) - \frac{0.936(220)^2}{142}\cos 75.6^\circ$$

$$\therefore V_S\cos(76.4 - \delta) = \frac{50 \times 142}{220} + 0.936 \times 220 \times 0.2486 = 32.27 + 51.19$$

$$V_S\cos(76.4 - \delta) = 83.46 \qquad ...(1)$$

Same as $Q_R = P_R\tan\phi = P_R\tan(\cos^{-1}\phi) = 50\tan(\cos^{-1}0.9)$

$= 24.21$ MW

$$Q_R = \frac{|V_S||V_R|}{|B|}\sin(\beta - \delta) - \frac{|A||V_R|^2}{|B|}\sin(\beta - \alpha)$$

$$= \frac{|V_S| \times 220}{142}\sin(76.4^\circ - \delta) - \frac{0.936 \times (220)^2}{142}\sin 75.6^\circ$$

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$$(24.21)\frac{142}{220} + 0.936 \times 220 \times 0.9685 = |V_S|\sin(76.4^\circ - \delta) \qquad ...(2)$$

from equation (1) & (2)

$$|V_S|^2 = (215)^2 + (83.46)^2$$

$$|V_S| = \sqrt{53190.5716} = 230.63 \text{ kV}$$

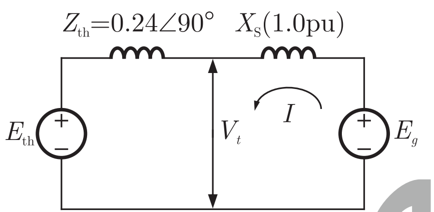
SOL 5.92 Option (B) is correct.

A new generator of $E_g = 1.4\angle 30^\circ$ pu

$X_S = 1.0$ pu, connected to bus of V_t Volt

Existing Power system represented by thevenin's equivalent as

$E_{th} = 0.9\angle 0^\circ$, $Z_{th} = 0.25\angle 90^\circ$, $V_t = ?$



From the circuit given

$$I = \frac{E_g - E_{th}}{Z_{th} + X_S} = \frac{1.4\angle 30^\circ - 0.9\angle 0^\circ}{j(1.25)} = \frac{1.212 + j7 - 0.9}{j(1.25)}$$

$$= \frac{0.312 + j7}{j(1.25)} = 0.56 - 0.2496j$$

$$V_t = E_g - IX_S = 1.212 + j7 - (0.56 - 0.2496j)(j1)$$

$$= 1.212 - 0.2496 + j(0.7 - 0.56) = 0.9624 + j0.14$$

$$V_t = 0.972\angle 8.3^\circ$$

SOL 5.93 Option (C) is correct.

Given that

3-ϕ Generator rated at 110 MVA, 11 kV

$X_d'' = 19\%$, $X_d' = 26\%$

$X_S = 130\%$, Operating at no load

3-ϕ short circuit fault between breaker and transformer

symmetrical I_{rms} at breaker = ?

We know short circuit current

$$I_{sc} = \frac{1}{X_d''} = \frac{1}{j0.19} = -j5.26 \text{ pu}$$

$$\text{Base current } I_B = \frac{\text{rating MVA of generator}}{\sqrt{3} \times \text{kV of generator}}$$

$$I_B = \frac{110 \times 10^6}{\sqrt{3} \times 11 \times 10^3}$$

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$$I_B = 5773.67 \text{ Amp}$$

$$\text{Symmetrical RMS current} = I_B \times I_{sc}$$

$$= 5773.67 \times 5.26 = 30369.50 \text{ Amp}$$

$$\Rightarrow I_{rms} = 30.37 \text{ kA}$$

SOL 5.94 Option (A) is correct.

$$+\text{ve sequence current } I_a = \frac{1}{3}[I_a + \alpha I_b + \alpha^2 I_c]$$

$$= \frac{1}{3}[10\angle 0^\circ + 1\angle 120^\circ \times 10\angle 180^\circ + 0]$$

$$= \frac{1}{3}[10\angle 0^\circ + 10\angle 300^\circ] = \frac{1}{3}[10 + 5 - j8.66]$$

$$= \frac{1}{3}[15 - j8.66] = \frac{17.32\angle -30^\circ}{3}$$

$$= 5.78\angle -30^\circ$$

SOL 5.95 Option (D) is correct.

Given data 500 MVA , 50 Hz, $3-\phi$ generator produces power at 22 kV

Generator $\rightarrow$ Y connected with solid neutral

Sequence reactance $X_1 = X_2 = 0.15$, $X_0 = 0.05$ pu

Sub transient line current = ?

$$I_{a1} = \frac{E}{Z_1 + Z_2 + Z_0} = \frac{1}{j0.15 + j0.15 + j0.05} = \frac{1}{0.35j} = -2.857j$$

Now sub transient Line current $I_a = 3I_{a1}$

$$I_a = 3(-2.857j) = -8.57j$$

SOL 5.96 Option (B) is correct.

Given: 50 Hz, 4-Pole, 500 MVA, 22 kV generator

p.f. = 0.8 lagging

Fault occurs which reduces output by 40%.

Accelerating torque = ?

$$\text{Power} = 500 \times 0.8 = 400 \text{ MW}$$

After fault, $\text{Power} = 400 \times 0.6 = 240 \text{ MW}$

$$\because P_a = T_a \times \omega$$

$$T_a = \frac{P_a}{\omega}$$

Where $\omega = 2\pi f_{\text{mechanical}}$

$$f_{\text{mechanical}} = f_{\text{electrical}} \times \frac{2}{P} = f_{\text{electrical}} \times \frac{2}{4}$$

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$$P_a = 400 - 240 = 160\text{ MW}$$
$$T_a = \frac{160}{2 \times \pi \times 50/2}$$
$$T_a = 1.018\text{ MN}$$

SOL 5.97 Option (D) is correct.

Turbine rate speed $N = 250$ rpm

To produce power at

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

No. of Poles $P = ?$

$$\because \; N = \frac{120}{P}f$$
$$P = \frac{120}{N}f = \frac{120 \times 50}{250} = 24$$
$$P = 24\text{ Poles}$$

SOL 5.98 Option (C) is correct.

In case of bundled conductors, We know that self GMD of conductor is increased and in a conductor critical disruptive voltage of line depends upon GMD of conductor. Since GMD of conductor is increased this causes critical disruptive voltage is being reduced and if critical disruptive voltage is reduced, the corona loss will also be reduced.

SOL 5.99 Option (B) is correct.

Given that no. of buses $n = 300$

Generator bus $= 20$

Reactive power support buses $= 25$

Fixed buses with Shunt Capacitor $= 15$

Slack buses $(n_s) = 20 + 25 - 15 = 30$

$\because$ Size of Jacobian Matrix is given as

$$= 2(n - n_s) \times 2(n - n_s)$$
$$= 2(300 - 30) \times 2(300 - 30)$$
$$= 540 \times 540$$

SOL 5.100 Option (B) is correct.

Auxiliary component in HVDC transmission system are DC line inductor and reactive power sources.

SOL 5.101 Option (C) is correct.

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$\because$ Exchanged electrical power is being given as follows

$$P = \frac{EV}{X_d}[\sin(\delta_1 - \delta_2)] \qquad ...(1)$$

Given that

$P \rightarrow$ Power supply by generator $= 0.5$ pu

$E \rightarrow$ Voltage for rotar generator $= 2.0$ pu

$V \rightarrow$ Voltage of motor rotor $= 1.3$ pu

$X_d = X_{eq} =$ Reactance of generator + Reactance of motor + Recatance of connecting line

$$X_d = 1.1 + 1.2 + 0.5 = 2.8$$

$\delta_1 - \delta_2 =$ Rotor angle difference = ?

from eq(1),
$$0.5 = \frac{2 \times 1.3}{2.8}\sin(\delta_1 - \delta_2)$$

$$\Rightarrow \delta_1 - \delta_2 = \sin^{-1}\left(\frac{2.8 \times 0.5}{2.6}\right)$$

$$\Rightarrow \delta_1 - \delta_2 = 32.58$$

SOL 5.102 Option (B) is correct.

Time period between energization of trip circuit and the arc extinction on an opening operation is known as the interrupting time of Circuit breaker.

SOL 5.103 Option (B) is correct.

Given that $ABCD$ parameters of line as

$$A = D = 0.9\angle 0^\circ,\ B = 200\angle 90^\circ\ \Omega,\ C = 0.95 \times 10^{-3}\angle 90^\circ\ \text{S}.$$

at no-load condition,

Receiving end voltage (V_R) = sending end voltage (V_S)

ohmic value of reactor = ?

We know
$$V_S = AV_R + BI_R$$
$$V_S = V_R$$
$$V_R = AV_R + BI_R$$
$$V_R(1 - A) = BI_R$$
$$\frac{V_R}{I_R} = \frac{B}{1 - A} = \frac{200\angle 90^\circ}{1 - 0.9\angle 0^\circ}$$
$$\frac{V_R}{I_R} = 2000\angle 90^\circ$$

The ohmic value of reactor $= 2000\ \Omega$

SOL 5.104 Option (A) is correct.

Surge impedance of cable

$$Z_1 = \sqrt{\frac{L}{C}}; \qquad L = 0.4\ \text{mH/km},\ C = 0.5\ \mu\text{F/km}$$

$$= \sqrt{\frac{0.4 \times 10^{-3}}{0.5 \times 10^{-6}}} = 28.284$$

surge impedance of overhead transmission line

$$Z_2 = Z_3 = \sqrt{\frac{L}{C}}; \qquad L = 1.5 \text{ mm/km}, C = 0.015\,\mu\text{F/km}$$

$$Z_2 = Z_3 = \sqrt{\frac{1.5 \times 10^{-5}}{0.015 \times 10^{-6}}} = 316.23$$

Now the magnitude of voltage at junction due to surge is being given by as

$$V' = \frac{2 \times V \times Z_2}{Z_2 + Z_1} \qquad V = 20 \text{ kV}$$

$$= \frac{2 \times 20 \times 10^3 \times 316.23}{316 + 28.284}$$

$$= 36.72 \text{ kV}$$

SOL 5.105 Option (D) is correct.

Let that current in line is I amp than

from figure current in line section PR is $(I - 10)$ amp

current in line section RS is $(I - 10 - 20) = (I - 30)$ amp

current in SQ Section is $(I - 30 - 30) = (I - 60)$ amp

Given that V_P and V_Q are such that

$$V_P - V_Q = 3 \text{ V}$$

by applying KVL through whole line

$$V_P - V_Q = (I - 10)0.1 + (I - 30)0.15 + (I - 60) \times 0.2$$

$$\Rightarrow 3 = 0.45I - 17.5$$

$$I = \frac{20.5}{0.45} = 45.55 \text{ amp}$$

Now the line drop is being given as

$$= (I - 10)0.1 + (I - 30)0.15 + (I - 60)0.2$$

$$= (33.55)0.1 + (15.55)0.15 + (14.45)0.2$$

$$= 8.58 \text{ V}$$

The value of V_P for minimum voltage of 220 V at any feeder is

$$= 220 + \text{Line voltage} = 220 + 8.58$$

$$= 228.58 \text{ V}$$

SOL 5.106 Option (D) is correct.

$$\text{Given Load Power} = 100 \text{ MW}$$

$$V_S = V_R = 11 \text{ kV}$$

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Impedance of line $Z_L = \frac{\text{p.u.} \times (\text{kV})^2}{\text{MV}} = \frac{j0.2 \times (11)^2}{100} = j0.242\,\Omega$

We know $$P_L = \frac{|V_S||V_R|\sin\delta}{X}$$

$$100 \times 10^6 = \frac{11 \times 10^3 \times 11 \times 10^3}{0.242}\sin\delta$$

$$\frac{100 \times 0.242}{121} = \sin\delta$$

$$\delta = \sin^{-1}(0.2) = 11.537^\circ$$

Reactive Power is being given by

$$Q_L = \frac{|V_S||V_R|}{X}\cos\delta - \frac{|V_R|^2}{X}$$

$$= \frac{11 \times 10^3 \times 11 \times 10^3}{0.242}\cos(11.537^\circ) - \frac{(11 \times 10^3)^2}{0.242}$$

$$= \frac{121 \times 10^6}{0.242}[\cos(11.537^\circ) - 1] = -10.1 \text{ MVAR}$$

SOL 5.107 Option (B) is correct.

Given the bus Impedance Matrix of a 4-bus Power System

$$Z_{\text{bus}} = \begin{bmatrix} j0.3435 & j0.2860 & j0.2723 & j0.2277 \\ j0.2860 & j0.3408 & j0.2586 & j0.2414 \\ j0.2723 & j0.2586 & j0.2791 & j0.2209 \\ j0.2277 & j0.2414 & j0.2209 & j0.2791 \end{bmatrix}$$

Now a branch os $j0.2\,\Omega$ is connected between bus 2 and reference

$$Z_{B_{(\text{New})}} = Z_{B(\text{Old})} - \frac{1}{Z_{ij} + Z_b}\begin{bmatrix} Z_{ij} \\ \vdots \\ Z_{nj} \end{bmatrix}\begin{bmatrix} Z_{ji} & \cdots & Z_{jn} \end{bmatrix}$$

New element $Z_b = j0.2\,\Omega$ is connected in j^{th} and reference bus

$j = 2$, $n = 4$ so

$$\frac{1}{Z_{ij} + Z_b}\begin{bmatrix} Z_{12} \\ Z_{22} \\ Z_{23} \\ Z_{24} \end{bmatrix}\begin{bmatrix} Z_{21} & Z_{22} & Z_{23} & Z_{24} \end{bmatrix}$$

$$= \frac{1}{[j(0.3408) + j0.2]}\begin{bmatrix} j0.2860 \\ j0.3408 \\ j0.2586 \\ j0.2414 \end{bmatrix}\begin{bmatrix} j0.2860 & j0.3408 & j0.2586 & j0.2414 \end{bmatrix} \quad ...(1)$$

Given that we are required to change only Z_{22}, Z_{23}

So in equation (1) $$Z'_{22} = \frac{j^2(0.3408)^2}{j(0.5408)} = j0.2147$$

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$$Z'_{23} = \frac{j^2(0.3408)(0.2586)}{0.5408} = j0.16296$$

$$Z_{22(\text{New})} = Z_{22(\text{Old})} - Z'_{22} = j0.3408 - j0.2147 = j0.1260$$

$$Z_{23(\text{New})} = Z_{23(\text{Old})} - Z'_{23} = j0.2586 - j0.16296 = j0.0956$$

SOL 5.108 Option (D) is correct.

Total zero sequence impedance, $+ve$ sequence impedance and $-ve$ sequence impedances

$$Z_0 = (Z_0)_{\text{Line}} + (Z_0)_{\text{Generator}} = j0.04 + j0.3 = j0.34 \text{ pu}$$

$$Z_1 = (Z_1)_{\text{Line}} + (Z_1)_{\text{Generator}} = j0.1 + j0.1 = j0.2 \text{ pu}$$

$$Z_2 = (Z_2)_{\text{Line}} + (Z_2)_{\text{Generator}} = j0.1 + j0.1 = j0.2 \text{ pu}$$

$$Z_n = j0.05 \text{ pu}$$

for L-G fault

$$I_{a1} = \frac{E_a}{Z_0 + Z_1 + Z_2 + 3Z_n} = \frac{0.1}{j0.2 + j0.2 + j0.34 + j0.15}$$

$$= -j1.12 \text{ pu}$$

$$I_B = \frac{\text{generator MVA}}{\sqrt{3}\,\text{generator kV}} = \frac{20 \times 10^6}{\sqrt{3} \times 6.6 \times 10^3} = 1750 \text{ Amp}$$

Fault current

$$I_f = (3I_a)I_B = 3(-j1.12)(1750) = -j5897.6 \text{ Amp}$$

Neutral Voltage

$$V_n = I_f Z_n$$

and $$Z_n = Z_B \times Z_{pu}$$

$$= \frac{(6.6)^2}{20} \times 0.05 = 0.1089\,\Omega$$

$$V_n = 5897.6 \times 0.1089 = 642.2 \text{ V}$$

SOL 5.109 Option (A) is correct.

We know that Optimal Generation

$$IC_1 = IC_2, \text{ and } P_3 = 300 \text{ MW (maximum load)}$$

$$IC_3 = 30 \qquad \text{(Independent of load)}$$

$$20 + 0.3P_1 = 30 + 0.4\,P_2$$

$$0.3P_1 - 0.4P_2 = 10 \qquad \text{...(1)}$$

$$P_1 + P_2 + P_3 = 700$$

$$P_1 + P_2 + 300 = 700$$

$$P_1 + P_2 = 400 \qquad \text{...(2)}$$

From equation (1) and (2)

$$P_1 = 242.8 \text{ MW}$$

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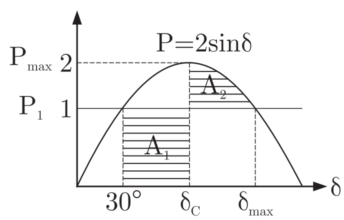
$$P_2 = 157.14 \text{ MW}$$

SOL 5.110 Option (A) is correct.

For transmission line protection-distance relay
For alternator protection-under frequency relay
For bus bar protection-differential relay
For transformer protection-Buchholz relay

SOL 5.111 Option (C) is correct.



We know by equal area criteria

$$P_S(\delta_m - \delta_0) = \int_{\delta_c}^{\delta_m} P_{max}\sin\delta\, d\delta$$

$$P_{max}\sin\delta_0(\delta_m - \delta_0) = P_{max}[\cos\delta_0 - \cos\delta_m] \quad ...(1)$$

$$P_{max} = 2$$

$$P_0 = P_{max}\sin\delta_0 = 1$$

$$\delta_0 = 30^\circ$$

$$\delta_{max} = 110^\circ \text{ (given)}$$

Now from equation (1)

$$2\sin 30^\circ(110 - 30)\frac{\pi}{180} = 2[\cos\delta_c - \cos 110^\circ]$$

$$0.5 \times \frac{80\pi}{180} = \cos\delta_c + 0.342$$

$$\cos\delta_c = 0.698 - 0.342$$

$$\delta_c = 69.138^\circ$$

SOL 5.112 Option (D) is correct.

$\because$ Both sides are granted

So, $$I_a = \frac{E_a}{Z_a} = \frac{10\angle 0^\circ}{2j} = 5\angle -90^\circ$$

$$I_b = \frac{E_b}{Z_b} = \frac{10\angle -90^\circ}{3j} = 3.33\angle -180^\circ$$

$$I_c = \frac{E_c}{Z_c} = \frac{10\angle 120^\circ}{4j} = 2.5\angle 30^\circ$$

We know $$I_{a_1} = \frac{1}{3}[I_a + \alpha I_b + \alpha^2 I_c]$$

where $\alpha = 1\angle 120° \Rightarrow \alpha^2 = 1\angle 240°$

$$I_{a1} = \frac{1}{3}[5\angle -90° + 3.33\angle(-180° + 120°) + 2.5\angle(240° + 30°)]$$

$$I_{a1} = \frac{1}{3}[5\angle -90° + 3.33\angle -60° + 2.5\angle 270°]$$

$$= \frac{1}{3}[-5j + 1.665 - j2.883 - 2.5j]$$

$$= \frac{1}{3}[1.665 - j10.383] = 3.5\angle -80.89°$$

SOL 5.113 Option (B) is correct.

Given data

A balanced delta connected load $= 8 + 6j = 2$

$$V_2 = 400 \text{ volt}$$

Improved Power Factor $\cos\phi_2 = 0.9$

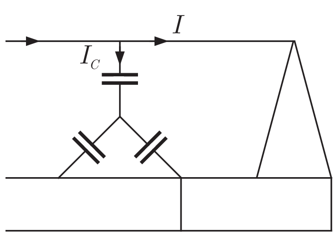
$$\phi_1 = \tan^{-1}(6/8) = 36.85°$$

$$\phi_2 = \cos^{-1}(0.9) = 25.84°$$

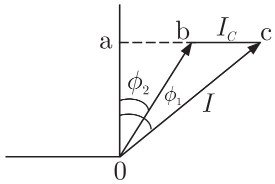
$$I = \frac{V}{Z} = \frac{400}{8+6j} = \frac{400}{10\angle 36.86°} = 40\angle -36.86°$$

$$= 32 - j24$$

Since Power factor is Improved by connecting a Y-connected capacitor bank like as



Phasor diagram is being given by as follows



In figure $\quad oa = I'\cos\phi_2 = I\cos\phi_1$

$$I'\cos 25.84° = 32$$

$$I' \times 0.9 = 32$$

$$I' = 35.55$$

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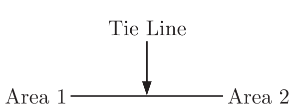
$$\text{ac} = 24 \text{ Amp.} \qquad (\text{ac} = I\sin\phi_1)$$
$$\text{ab} = I'\sin\phi_2 = 35.55\sin 25.84^\circ$$
$$\text{ab} = 15.49 \text{ Amp}$$
$$I_c = \text{bc} = \text{ac} - \text{ab} = 24 - 15.49 = 8.51 \text{ Amp}$$
$$\text{KVAR of Capacitor bank} = \frac{3 \times V \times I_C}{1000} = \frac{3 \times 400 \times 8.51}{1000}$$
$$= 10.2 \text{ KVAR}$$

SOL 5.114 Option (B) is correct.
Given power system with these identical generators
G1 has Speed governor
G2 and G3 has dr0op of 5%
When load increased, in steady state generation of G1 is only increased while generation of G2 and G3 are unchanged.

SOL 5.115 Option (A) is correct.
R_1, R_2-Distance Relay
Zone-1 and Zone-2 setting for both the relays
Correct setting for Zone-2 of relay R_1 and R_2 are given as
$TZ2_{R_1} = 0.6\text{sec}$, $TZ_{R_2} = 0.3$ sec
$\because$ Fault at Zone-2, therefore firstly operated relay is R_2, so time setting of R_2 is 0.3 sec and R_1 is working as back up relay for zone-2, so time setting for R_1 is 0.6 sec.

SOL 5.116 Option (B) is correct.
The reactive power absorbed by the rectifier is maximum when the firing angle $\alpha = 30^\circ$.

SOL 5.117 Option (D) is correct.
Given a power system consisting of two areas as shown connected by single tie-line



For load flow study when entering the network data, the tie line data inadvertently left out. If load flow programme is run with this incomplete data than load flow will not converge if only one slack bus is specified.

SOL 5.118 Option (D) is correct.
Given that $X_S = 0.2$ pu

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Mid point voltage of transmission line = 0.98 pu

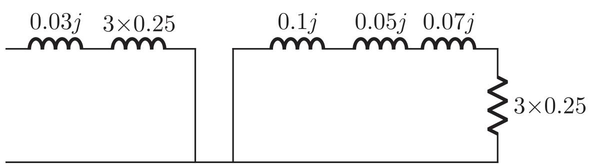
$$V_S = V_R = 1$$

Steady state power transfer limit

$$P = \frac{V_S V_R}{X_S} \sin \delta = \frac{1.1}{0.2} \sin 90^\circ = 5 \text{ pu}$$

SOL 5.119 Option (B) is correct.

We have to find out the thevenin's equivalent zero sequence impedance Z_0 at point B.The zero sequence network of system can be drawn as follows



equivalent zero sequence impedance is being given as follows

$$Z_0 = 0.1j + 0.05j + 0.07j + (3 \times 0.25)$$

$$Z_0 = 0.75 + j0.22$$

SOL 5.120 *Given data :

$$Z_C = 400\,\Omega \text{ (Characteristics Impedance)}$$

$$\beta = 1.2 \times 10^{-3} \text{ rad/km (Propagation constant)}$$

$$l = 100 \text{ km (length of line)}$$

$$P_{max} = ? \text{ If } V_S = 230 \text{ kV}$$

$$V_S = V_R \cos(\beta l) + jZ_C \sin(\beta l) I_R$$

$$V_S = A V_R + B I_R$$

$$A = \cos \beta l$$

$$= \cos(1.2 \times 10^{-3} \times 100) = 0.9928\angle 0^\circ$$

$$B = jZ_C \sin(\beta l)$$

$$= j400 \sin(1.2 \times 10^{-3} \times 100) = j47.88$$

$$= 47.88\angle 90^\circ$$

$$V_S = 230 \text{ kV}, \; l = 100 \text{ km}$$

Since it is a short line, so $V_S \simeq V_R = 230$ kV

again we know for transmission line the equation

$$(P_r - P_{r0})^2 + (Q_r - Q_{r0}) = P_r^2 \qquad \text{...(1)}$$

Where $$P_{r0} = -\frac{A V_R^2}{B} \cos(\beta - \alpha) \text{ MW}$$

$$Q_{r0} = -\frac{A V_R^2}{B} \sin(\beta - \alpha) \text{ MW}$$

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$$P_r = \frac{V_S V_R}{B} \text{ MVA}$$

and maximum power transferred is being given by as

$$P_{rm} = |P_r| - |P_{r0}|$$

$$P_r = \frac{V_S V_R}{B} = \frac{230 \times 230}{47.88}$$

$$P_r = 1104.84 \text{ MVA}$$

$$P_{r0} = -\frac{A V_R^2}{B} \cos(\beta - \alpha) \text{ MW}$$

$$= -\frac{0.9928 \times (230)^2}{47.88} \times \cos(90^\circ - 0)$$

$$P_{r0} = 0 \text{ MW}$$

So maximum Power transferred

$$P_{rm} = |P_r| - |P_{r0}| = 1104.84 \text{ MW}$$

SOL 5.121 *Given: two transposed 3-ϕ line run parallel to each other.

The equation for voltage drop in both side are given as

$$\begin{bmatrix} \Delta V_{a1} \\ \Delta V_{b1} \\ \Delta V_{c1} \\ \Delta V_{a2} \\ \Delta V_{b2} \\ \Delta V_{c2} \end{bmatrix} = j \begin{bmatrix} 0.15 & 0.05 & 0.05 & 0.04 & 0.04 & 0.04 \\ 0.05 & 0.15 & 0.05 & 0.04 & 0.04 & 0.04 \\ 0.05 & 0.05 & 0.15 & 0.04 & 0.04 & 0.04 \\ 0.04 & 0.04 & 0.04 & 0.15 & 0.05 & 0.05 \\ 0.04 & 0.04 & 0.04 & 0.05 & 0.15 & 0.05 \\ 0.04 & 0.04 & 0.04 & 0.05 & 0.05 & 0.15 \end{bmatrix} \begin{bmatrix} I_{a1} \\ I_{b1} \\ I_{c1} \\ I_{a2} \\ I_{b2} \\ I_{c2} \end{bmatrix}$$

We have to compute self and mutual zero sequence impedance of the system i.e. $Z_{011}, Z_{012}, Z_{021}, Z_{022}$ in the following equation.

$$\Delta V_{01} = Z_{011} I_{01} + Z_{021} I_{02}$$

$$\Delta V_{02} = Z_{021} I_{01} + Z_{022} I_{02}$$

We know that +ve, −ve and zero sequence Impedance can be calculated as respectively.

$$Z_1 = j(X_S - X_m)$$

$$Z_2 = j(X_S - X_m)$$

$$Z_0 = j(X_S + 2X_m)$$

So zero sequence Impedance calculated as

$$Z_{011} = j(X_S + 2X_m) \qquad X_S = 0.15,\ X_m = 0.05$$

$$Z_{011} = j[0.15 \times 2(0.05)] = 0.25j$$

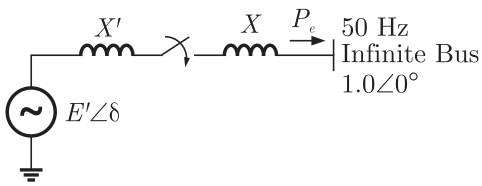
$$Z_{012} = Z_{021} = j(X_S + 2X_m) \qquad X_S = 0.15,\ X_m = 0.04$$

$$Z_{012} = Z_{021} = j[0.15 + 2(0.04)] = 0.23j$$

$$Z_{022} = j(X_S + 2X_m) \qquad X_S = 0.15,\ X_m = 0.05$$

$$= j[0.15 + 2(0.01)]$$
$$= 0.25j$$

SOL 5.122 *Given



$$X = 0.2 \text{ pu}$$

For generator $X' = 0.1\,\text{pu},\ E' = 1.0\,\text{pu}, H = 5\,\text{MJ/MVA}$

Mechanical Power $P_m = 0.0\,\text{pu}, \omega_B = 2\pi \times 50$ rad/sec

Initially generator running on open circuit, at switch closure $\delta = 0$

$$\omega_B = \frac{d\delta}{dt} = \omega_{\text{init}}$$

maximum $\omega_{\text{init}} = ?$, so that generator pulls into synchronism

We know that swing equation

$$\frac{H}{\pi f}\frac{d^2\delta}{dt^2} = (P_m - P_e) \text{ pu} \qquad ......(1)$$

$$P_e = \frac{|E||V|}{X}\sin\delta = \frac{1.1}{0.3}\sin\delta = 3.33\sin\delta$$

From equation (1)

$$\frac{5}{3.14 \times 50}\frac{d^2\delta}{dt^2} = 0 - 3.33\sin\delta$$

$$\frac{d^2\delta}{dt^2} = -104.72\sin\delta$$

integrating on both side.

$$\frac{d\delta}{dt} = 104.72\cos\delta + \delta_0$$

$$\delta_0 = 0 \text{ (given)}$$

$$\omega = \frac{d\delta}{dt}$$

For $(\omega_{\text{init}})_{\max} = \left(\frac{d\delta}{dt}\right)_{\max}$

$\left(\frac{d\delta}{dt}\right)_{\max}$ when $\cos\delta = 1$

$$(\omega_{\text{init}})_{\max} = \left(\frac{d\delta}{dt}\right)_{\max} = 104.72 \text{ rad/sec}$$

SOL 5.123 Option (C) is correct.

A lossless radial transmission line with surge impedance loading has flat

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voltage profile and unity power factor at all points along it.

SOL 5.124 Option (B) is correct.

Given that 3-ϕ transformer, 20 MVA, 220 kV(Y) - 33 kV(Δ)

$$X_l = \text{leakage Reactance} = 12\%$$

$$X = \text{reffered to LV in each phase} = ?$$

$$= 3 \times \frac{(\text{LV side voltage})^2}{\text{MVA Rating}} \times \text{Reactance of Leakage}$$

$$= 3 \times \frac{(33\,\text{kV})^2}{20\,\text{MVA}} \times 0.12 = 19.6\,\Omega$$

SOL 5.125 Option (D) is correct.

Given 75 MVA, 10 kV synchronous generator

$$X_d = 0.4\text{ pu}$$

We have to find out $(X_d)_{\text{new}}$ at 100 MVA, 11 kV

$$(X_d)_{\text{new}} = (X_d)_{\text{old}} \times \left[\frac{(\text{kV})_{\text{old}}}{(\text{kV})_{\text{new}}}\right]^2 \times \left[\frac{(\text{MVA})_{\text{new}}}{(\text{MVA})_{\text{old}}}\right]$$

$$(X_d)_{\text{new}} = 0.4 \times \left(\frac{10}{11}\right)^2 \times \frac{100}{75} = 0.44\text{ pu}$$

SOL 5.126 Option (A) is correct.

Given Y-alternator: 440 V, 50 Hz

Per phase $X_s = 10\,\Omega$, Capacitive Load current $I = 20$ A

For zero voltage regulation load p.f = ?

$$\text{Let Load } Z = R + jX$$

Zero voltage regulation is given so

$$\overline{E}_{\text{Ph}} - IX_s - I(R + jX) = 0$$

$$\frac{440}{\sqrt{3}} - 20(j10) - 20(R + jX) = 0 \qquad ...(1)$$

separating real and imaginary part of equation (1)

$$20R = \frac{440}{\sqrt{3}}$$

$$R = \frac{22}{\sqrt{3}}$$

and

$$20(X + 10) = \frac{440}{\sqrt{3}}$$

$$X = \frac{22}{\sqrt{3}} - 10 = \frac{4.68}{\sqrt{3}}$$

$$\theta = \tan^{-1}\frac{X}{R} = \tan^{-1}\left(\frac{4.68/\sqrt{3}}{22/\sqrt{3}}\right) = \tan^{-1}\left(\frac{4.68}{22}\right)$$

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and power factor $\cos\theta = \cos\left(\tan^{-1}\frac{4.68}{22}\right)$

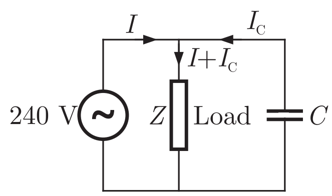
$$\cos\theta = 0.82$$

SOL 5.127 Option (B) is correct.

Given 240 V, 1-ϕ AC source, Load Impedance $Z = 10\angle 60^\circ\,\Omega$

Capacitor is in parallel with load and supplies 1250 VAR

The real power P by source$=$?



from figure current through load $I_L = I + I_C$

$$I = \frac{V}{Z} = \frac{240}{10\angle 60^\circ} = 24\angle -60^\circ$$

$$I_C = \frac{\text{VAR}}{V} = \frac{1250}{240} = 5.20j$$

$$I_L = 24\angle -60^\circ + 5.20j = 12 - 15.60j$$

$\because$ apparent power $S = VI = P + jQ = 240\,(12 + 15.60j)$

$$= 2880 + 3744j = P + jQ$$

Where $P =$ Real Power, $Q =$ Reactive Power

$$P = 2880 \text{ W}$$

SOL 5.128 Option ( ) is correct.

SOL 5.129 Option (C) is correct.

We have to find out maximum voltage location on line

by applying KVL in the circuit

$$V_S - V_R = 0.05j, \text{ where } V_S = 1$$

$$V_R = 1 - 0.05j$$

voltage at $P_1 = V_S = 1\,\text{pu.}$ ..(1)

voltage at $P_2 = 1 - 0.1j$ (by applying KVL) ...(2)

voltage at $P_3 = 1 - 0.1j + j0.15$ (by applying KVL)

$= 1 + 0.05j$ ...(3)

From equation (1), (2) and (3) it is cleared that voltage at P_3 is maximum.

SOL 5.130 Option (B) is correct.

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Given: two generators $P_1 = 50(50 - f)$

$$P_2 = 100(51 - f)$$

total load = 400 MW than $f = ?$

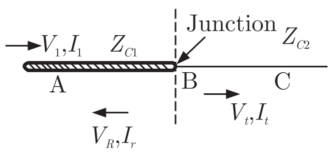
$$P_1 + P_2 = 400$$

$$50(50 - f) + 100(51 - f) = 400$$

$$50 + 102 - 8 = 3f$$

$$f = 48\,\text{Hz}$$

SOL 5.131 *Given 132 kV transmission line connected to cable as shown in figure



Characteristics impedance of line and cable are 400 Ωand 80 Ω
250 kV surge travels from A to B than

(a) We have to calculate voltage surge at C.

(b) Reflected component of surge when reaches A.

(c) Surge current in cable BC

$V_i = 250\,\text{kV},\ Z_{C1} = 400\,\Omega,\ Z_{C2} = 80\,\Omega$

(a) Voltage surge at C

$$V_t = \frac{Z \times Z_{C2}}{Z_{C1} + Z_{C2}} \times V_i = \frac{2 \times 80}{400 + 80} \times 250 = 83.34\,\text{kV}$$

(b) Reflected voltage at A

$$V_r = \left(\frac{Z_{C2} - Z_{C1}}{Z_{C2} + Z_{C1}}\right) V_i = \frac{80 - 400}{400 + 80} \times 250 = -166.67\ \text{kV}$$

(c) Surge current in cable BC

$$I_t = I_i + I_r = I_i - \alpha I_i$$

$$= (1 - \alpha) I_i,\ \text{Here } \alpha = \frac{Z_{C2} - Z_{C1}}{Z_{C2} + Z_{C1}}$$

$$I_t = \left(1 - \frac{Z_{C2} - Z_{C1}}{Z_{C2} + Z_{C1}}\right)\frac{V_i}{Z_{C1}} = \left(1 + \frac{320}{480}\right)\frac{250}{400}$$

$$= \left(1 + \frac{4}{6}\right)\frac{25}{40} = 1.04\ \text{kAmp}$$

SOL 5.132 *We have to draw reactance diagram for given Y_{Bus} matrix

$$Y_{\text{Bus}} = j\begin{bmatrix} -6 & 2 & 2.5 & 0 \\ 2 & -10 & 2.5 & 4 \\ 2.5 & 2.5 & -9 & 4 \\ 0 & 4 & 4 & -8 \end{bmatrix}$$

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$\because$ It is 4×4 matrix (admittance matrix) as

$$Y_{Bus} = \begin{bmatrix} y_{11} & y_{12} & y_{13} & y_{14} \\ y_{21} & y_{22} & y_{23} & y_{24} \\ y_{31} & y_{32} & y_{33} & y_{34} \\ y_{41} & y_{42} & y_{43} & y_{44} \end{bmatrix}$$

Here diagonal elements

$$y_{11} = y_{10} + y_{12} + y_{13} + y_{14} = -6j \qquad ...(1)$$

$$y_{22} = y_{20} + y_{21} + y_{23} + y_{24} = -10j \qquad ...(2)$$

$$y_{33} = y_{30} + y_{31} + y_{32} + y_{34} = -9j \qquad ...(3)$$

$$y_{44} = y_{40} + y_{41} + y_{42} + y_{43} = -9j \qquad ...(4)$$

and diagonal elements

$$\left.\begin{aligned} y_{12} = y_{21} &= -y_{12} = 2j \\ y_{13} = y_{31} &= -y_{13} = 2.5j \\ y_{14} = y_{41} &= -y_{14} = 0j \\ y_{23} = y_{32} &= -y_{23} = 2.5j \\ y_{24} = y_{42} &= -y_{24} = 4j \\ y_{34} = y_{34} &= 4j \end{aligned}\right\} \qquad .....(5)$$

from equation (1) $y_{10} = y_{11} - y_{12} - y_{13} - y_{14} = -6j + 2j + 2.5j + 0j = -1.5j$

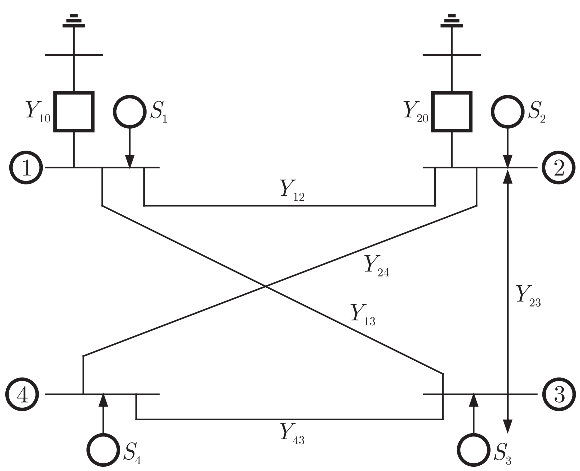
Same as from equation (2)

$$y_{20} = y_{22} - y_{21} - y_{23} - y_{24} = -10j + 2j + 2.5j + 4j = -1.5j$$

from equation (3) $y_{30} = y_{33} - y_{31} - y_{32} - y_{34} = -9j + 2.5j + 2.5j + 4j = 0$

from equation (4) $y_{40} = y_{44} - y_{41} - y_{42} - y_{43} = -8j + 0 + 4j + 4j = 0$

Now we have to draw the reactance diagram as follows



SOL 5.133 *Given synchronous generator is connected to infinite bus through loss less double circuit line

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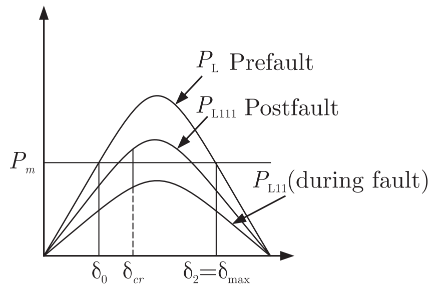
$$P_d = 1\angle 30° \text{ pu}$$

sudden fault reduces the peak power transmitted to 0.5 pu
after clearance of fault, peak power = 1.5 pu
Critical clearing angle (δ_{cr})= ?



$$\delta_0 = 30° = 0.52 \text{ rad}$$

From equal area criteria

$$\int_{\delta_0}^{\delta_{cr}} (P_{L11} - P_{\max 11}\sin\delta)\, d\delta = \int_{\delta_{cr}}^{\delta_{\max}} (P_{\max 111}\sin\delta - P_m)\, d\delta \qquad ...(1)$$

Where $\delta_{\max} = \pi - \sin^{-1}\left(\frac{P_m}{P_{\max 111}}\right)$

$$\delta_{\max} = \pi - 0.8729 = 2.41 \text{ rad}$$

By integrating equation (1)

$$[P_m\delta + P_{\max 11}\cos\delta]_{\delta_{cr}}^{\delta_{\max}} + P_{\max 111}(\cos\delta_{\max} - \cos\delta_{cr}) = 0$$

$$\Rightarrow \quad P_m(\delta_{cr} - \delta_\sigma) + P_{\max 11}(\cos\delta_{cr} - \cos\delta_0) + P_m(\delta_{\max} - \delta_{cr})$$
$$+ P_{\max 111}(\cos\delta_{\max} - \cos\delta_{cr}) = 0$$

$$\Rightarrow \quad \cos\delta_{cr} = \frac{P_m(\delta_{\max} - \delta_0) - P_{\max 11}\cos\delta_0 + P_{\max 111}\cos\delta_{\max}}{P_{\max 111} - P_{\max 11}}$$

$$= \frac{1(2.41 - 0.52) - 0.5\cos(0.52) + 1.5\cos(2.41)}{1.5 - 0.5}$$

$$\cos\delta_{cr} = 0.35$$

$$\delta_{cr} = \cos^{-1}0.35 = 1.21 \text{ rad}$$

SOL 5.134 *Given: L - G fault on unloaded generator

$Z_0 = j0.15,\ Z_1 = j0.25,\ Z_2 = j0.25$ pu, $Z_n = j0.05$ pu

$$V_{\text{prefault}} = 1 \text{ pu}$$

$$I_f = ?$$

Fault Current

$$I_f = 3I_{a1} = \frac{3V_{\text{prefault}}}{Z_1 + Z_2 + Z_0 + 3Z_n} = \frac{3\times 1}{(j0.25 + j0.25 + j0.15) + 3(j.05)}$$

$$= \frac{3}{0.80j} = -3.75j$$

Sequence network is being drawn as follows

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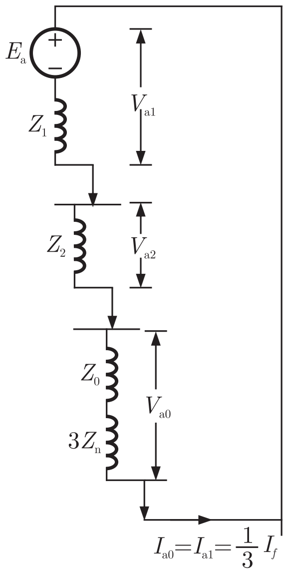

SOL 5.135 *Given power system has two generator

Generator - 1; $C_1 = 0.006P_{G1}^2 + 8P_{G1} + 350$

Generator - 2; $C_2 = 0.009P_{G2}^2 + 7P_{G2} + 400$

Generator Limits are $100\text{ MW} \le P_{G1} \le 650\text{ MW}$

$50\text{ MW} \le P_{G2} \le 500\text{ MW}$

$P_{G1} + P_{G2} = 600\text{ MW}$, $P_{G1}, P_{G2} = ?$ For optimal generation

We know for optimal Generation

$$\frac{\partial C_1}{\partial P_{G1}} = \frac{\partial C_2}{\partial P_{G2}} \quad ...(1)$$

$$\frac{\partial C_1}{\partial P_{G1}} = 0.012P_{G1} + 8$$

$$\frac{\partial C_2}{\partial P_{G2}} = 0.018P_{G2} + 7$$

from equation (1)

$$0.012P_{G1} + 8 = 0.018P_{G2} + 7$$

$$0.012P_{G1} - 0.018P_{G2} = -1 \quad ...(2)$$

$$P_{G1} + P_{G2} = 600 \quad ...(3)$$

From equation (2)

$$0.012P_{G1} - 0.018(600 - P_{G1}) = -1$$

$\Rightarrow$ $0.03P_{G1} = 9.8$

$\Rightarrow$ $P_{G1} = 326.67\text{ MW}$

$$P_{G2} = 600 - P_{G1} = 600 - 326.67 = 273.33\text{ MW}$$

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Contents

VOLUME-1

VOLUME-2

UNIT 5 CONTROL SYSTEM

UNIT 6 ELECTRICAL & ELECTRONIC MEASUREMENTS

UNIT 7 ANALOG & DIGITAL ELECTRONICS