4 Power System Studies

4.1 - Load Flows

Multiple Choice Questions

Q.1 The principal information obtained from load flow studies in a power system are

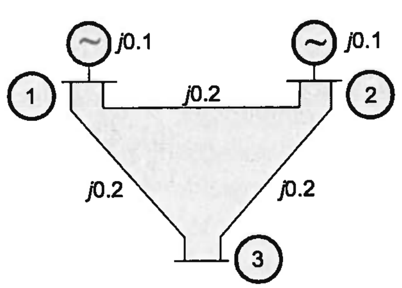
1. magnitude and phase angle of the voltage at each bus.
2. reactive and real power flows in each of the lines.
3. total power loss in the network.
4. transient stability limit of the system.

Select the correct answer using the codes given below:

(a) 1 and 2 (b) 3 and 4
(c) 1, 2 and 3 (d) 2 and 4

[ESE-2001]

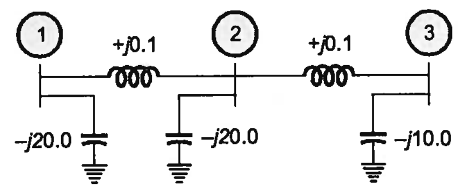
Q.2 A sample power system network is shown in the figure given below. The reactances marked are in pu. What is the pu value of Y_{22} of the Bus Admittance Matrix (Y_{BUS})?



(a) j10.0 (b) j0.4
(c) $-j$0.1 (d) $-j$20.0

[ESE-2005]

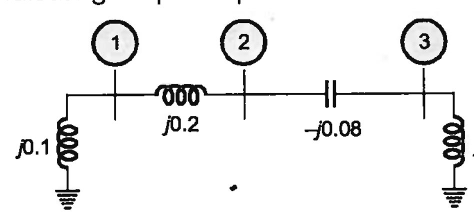
Q.3 The network shown in the given figure has impedances in p.u. as indicated. The diagonal element Y_{22} of the bus admittance matrix Y_{BUS} of the network is



(a) $-j$19.8 (b) $+j$20.0
(c) $+j$0.2 (d) $-j$19.95

[GATE-2005]

Q.4 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) $j\begin{bmatrix} -10 & 5 & 0 \\ 5 & 7.5 & 12.5 \\ 0 & 12.5 & -10 \end{bmatrix}$

[GATE-2011]

Q.5 A power system consists of 300 buses out of which 20 buses are generator buses, 25 buses are the ones with reactive power support and 15 buses are ones with fixed shunt capacitors. All the other buses are load buses. It is proposed to perform a load flow analysis for the system using Newton-Raphson Jacobian matrix is

(a) 553 × 553 (b) 540 × 540
(c) 555 × 555 (d) 554 × 554

[GATE-2003]

Q.6 Which one of the following statements is correct?

The elements of each row of a Y_{BUS} matrix for load flow studies in power system add up to zero,

(a) always
(b) if the shunt admittances at the buses are ignored
(c) if mutual couplings between transmission lines are absent
(d) if both (b) and (c) are satisfied

[ESE-2006]

Q.7 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 for the two systems, corresponding to this scenario. The bus voltage phasors so obtained 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 $P_1 = P_2 = Q_1 = Q_2 = 0$.

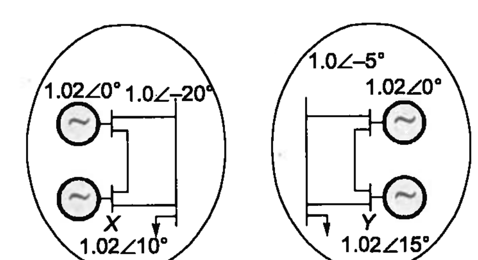


Figure A

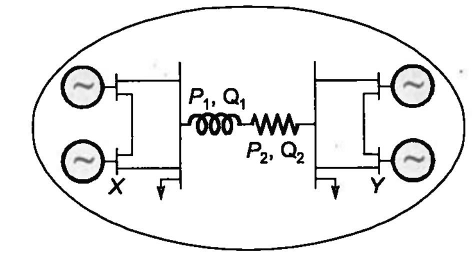


Figure B

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

(a) 10° (b) 25°
(c) –30° (d) 30°

[GATE-2007]

Q.8 For the Y-bus matrix of a 4-bus system given in per unit, the buses having shunt elements are

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

(a) 3 and 4 (b) 2 and 3
(c) 1 and 2 (d) 1, 2 and 4

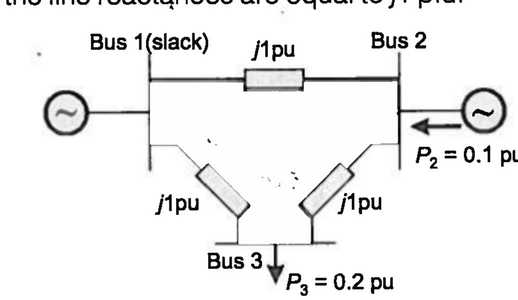
[GATE-2009]

Q.9 What is the form of the Y_{bus} matrix for carrying out load flow studies by Gauss-Seidal method of a power system having mesh connection of nodes?

(a) Symmetric but not diagonal matrix
(b) Diagonal matrix
(c) Antisymmetric matrix
(d) Sparse asymmetric matrix

[ESE-2009]

Statement for Linked Answer Questions (10 and 11):
In the following network, the voltage magnitudes at all buses are equal to 1 p.u., the voltage phase angles are very small, and the line resistances are negligible. All the line reactances are equal to j1 p.u.



Q.10 The voltage phase angles in rad at buses 2 and 3 are

(a) $\theta_2 = -0.1, \theta_3 = -0.2$
(b) $\theta_2 = 0, \theta_3 = -0.1$
(c) $\theta_2 = 0.1, \theta_3 = 0.1$
(d) $\theta_2 = 0.1, \theta_3 = 0.2$

[GATE-2013]

Q.11 If the base impedance and the line-to-line base voltage are 100 Ω and 100 kV, respectively, then the real power in MW delivered by the generator connected at the slack bus is

(a) –10 (b) 0
(c) 10 (d) 20

[GATE-2013]

Q.12 In a 100 bus power system, there are 10 generators. In a particular iteration of Newton Raphson load flow technique (in polar coordinates), two of the *PV* buses are converted to *PQ* type. In this iteration,

(a) the number of unknown voltage angles increases by two and the number of unknown voltage magnitudes increases by two.
(b) the number of unknown voltage angles remains unchanged and the number of unknown voltage magnitudes increases by two.
(c) the number of unknown voltage angles increases by two and the number of unknown voltage magnitudes decreases by two.
(d) the number of unknown voltage angles remains unchanged and the number of unknown voltage magnitudes decreases by two.

[GATE-2016]

Q.13 A power system has 100 buses including 10 generator buses. For the load flow analysis using Newton-Raphson method in polar coordinates, the size of the Jacobian is

(a) 189 × 189 (b) 100 × 100
(c) 90 × 90 (d) 180 × 180

Numerical Data Type Questions

Q.14 The *Z* matrix of a 2-port network as given by:

$$\begin{bmatrix} 0.9 & 0.2 \\ 0.2 & 0.6 \end{bmatrix}$$

The element Y_{22} of the corresponding *Y* matrix of the same network is given by _____ .

[GATE-2004]

Q.15 The Y_{BUS} matrix of a 100-bus interconnected system is 90% sparse. Hence the number of transmission lines in the system must be _____.

[ESE-2002]

Q.16 The bus admittance matrix of a three-bus three-line system is

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

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 _____ .

[GATE-2012]

Q.17 A 183-bus power system has 150 PQ buses and 32 PV buses. In the general case, to obtain the load flow solution using Newton-Raphson method in polar co-ordinates, the minimum number of simultaneous equations to be solved is _____ .

[GATE-2014]

4.2 - Fault Analysis

Multiple Choice Questions

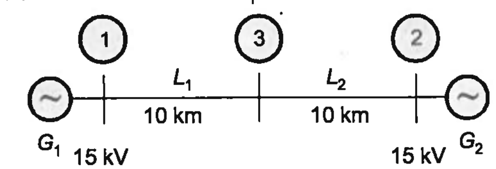
Q.18 The sequence components of the fault current are as follows:

$I_{positive} = j1.5$ pu, $I_{negative} = -j0.5$ pu, $I_{zero} = -j1$ pu.

The type of fault in the system is

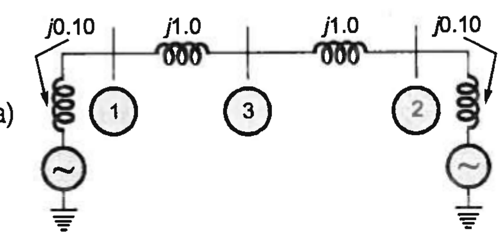
(a) LG (b) LL
(c) LLG (d) LLLG **[GATE-2012]**

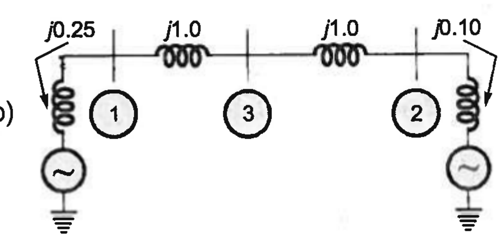
Statement for Linked Answer Questions (19 and 20):
Two generator units G_1 and G_2 are connected by 15 kV line with a bus at the mid-point as shown below,

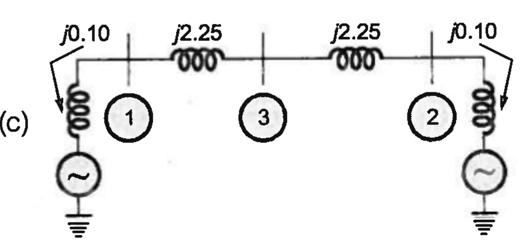


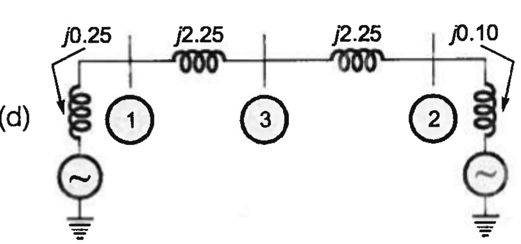
G_1 = 250 MVA, 15 kV, positive sequence reactance X = 25% on its own base.
G_2 = 100 MVA, 15 kV, positive sequence reactance X = 10% on its own base.
L_1 and L_2 = 10 km, positive sequence reactance X = 0.225 Ω/km .

Q.19 For the above system, the positive sequence diagram with the p.u. values on the 100 MVA common base is

(a)


(b)


(c)


(d)


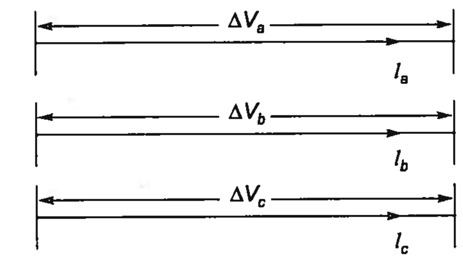
[GATE-2011]

Q.20 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

[GATE-2011]

Q.21 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 neglected. If the line 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) $Z_s = 11\ \Omega$; $Z_m = 26\ \Omega$

[GATE-2008]

Q.22 When a 50 MVA, 11 kV, 3-phase generator is subjected to a 3-phase fault, the fault current is –*j*5 pu (per unit). When it is subjected to a line-to-line fault, the positive sequence current is –*j*4 pu. The positive and negative sequence reactances are respectively

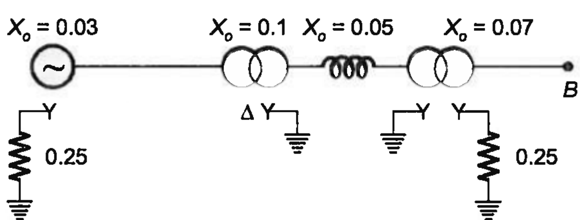
(a) *j* 0.2 and *j* 0.05 pu
(b) *j* 0.2 and *j* 0.25 pu
(c) *j* 0.25 and *j* 0.25 pu
(d) *j* 0.05 and *j* 0.05 pu **[ESE-1997]**

Q.23 A star-connected 3-phase 11 kV, 25 MVA alternator with its neutral grounded through a 0.033 pu reactance (based on the alternator rating) has positive, negative and zero-sequence reactances of 0.2 pu, 0.1 pu and 0.1 pu respectively. A single line to ground fault on one of its terminals would result in a short circuit capacity

(a) 150 MVA (b) 125 MVA
(c) 100 MVA (d) 50 MVA

[ESE-1999]

Q.24 A generator is connected to a transformer which feeds another transformer through a short feeder (see figure). The zero sequence impedance values are expressed in p.u. 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) $1.5 + j0.25$

[GATE-2002]

Q.25 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 the 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

[GATE-2003]

Q.26 A 500 MVA, 50 Hz, 3-phase turbo-generator produces power at 22 kV. Generator is λ-connected and its neutral is solidly grounded. Its sequence reactances are $X_1 = X_2 = 0.15$ 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

[GATE-2004]

Statement for Linked Answer Questions (27 and 28):
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 susceptance of the system.

Q.27 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

[GATE-2005]

Q.28 And 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

[GATE-2005]

Q.29 A fault occurring at the terminals of an unloaded synchronous generator operating at its rated voltage has resulted in the following values of currents and voltages:

$I_{a0} = j\,2.37$ pu,
$I_{a1} = -j\,3.05$ pu, $I_{a2} = j\,0.68$ pu,
$V_{a0} = V_{a1} = V_{a2} = 0.237$ pu

Which one of the following faults has occurred?

(a) L-L fault (b) L-G fault
(c) L-L-G fault (d) L-L-L fault

[ESE-2005]

Q.30 The current of a single phase load drawn from a 3-phase system has

(a) Zero sequence component of current as zero
(b) Negative sequence component of current more than positive sequence component
(c) Positive, negative and zero sequence components equal
(d) Negative sequence component of current less than positive sequence component

[ESE-2011]

Statement for Common Data Questions (31 and 32):
For a power system the admittance and impedance matrices for the fault studies are as follows.

$$Y_{bus} = \begin{bmatrix} -j\,8.75 & j\,1.25 & j\,2.50 \\ j\,1.25 & -j\,6.25 & j\,2.50 \\ j\,2.50 & -j\,2.50 & -j\,5.00 \end{bmatrix}$$

$$Z_{bus} = \begin{bmatrix} j\,0.16 & j\,0.08 & j\,0.12 \\ j\,0.08 & j\,0.24 & j\,0.16 \\ j\,0.12 & j\,0.16 & j\,0.34 \end{bmatrix}$$

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

Q.31 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

[GATE-2006]

Q.32 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

[GATE-2006]

Q.33 The bus impedance matrix of a 4-bus power system is given by

$$Z_{bus} = \begin{bmatrix} j\,0.3435 & j\,0.2860 & j\,0.2723 & j\,0.2277 \\ j\,0.2860 & j\,0.3408 & j\,0.2586 & j\,0.2414 \\ j\,0.2723 & j\,0.2586 & j\,0.2791 & j\,0.2209 \\ j\,0.2277 & j\,0.2414 & j\,0.2209 & j\,0.2791 \end{bmatrix}$$

A branch having an impedance of $j\,0.2\ \Omega$ 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) $j\,0.5408\ \Omega$ and $j\,0.4586\ \Omega$
(b) $j\,0.1260\ \Omega$ and $j\,0.0956\ \Omega$
(c) $j\,0.5408\ \Omega$ and $j\,0.0956\ \Omega$
(d) $j\,0.1260\ \Omega$ and $j\,0.1630\ \Omega$

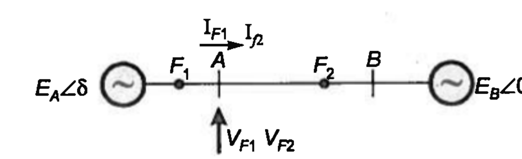
[GATE-2003]

Q.34 For a fully transposed transmission line

(a) positive, negative and zero sequence impedances are equal
(b) positive and negative sequence impedances are equal
(c) zero and positive sequence impedances are equal
(d) negative and zero sequence impedances are equal

[GATE-2014]

Q.35 Three-phase to ground fault takes place at locations F_1 and F_2 in the system shown in the figure.

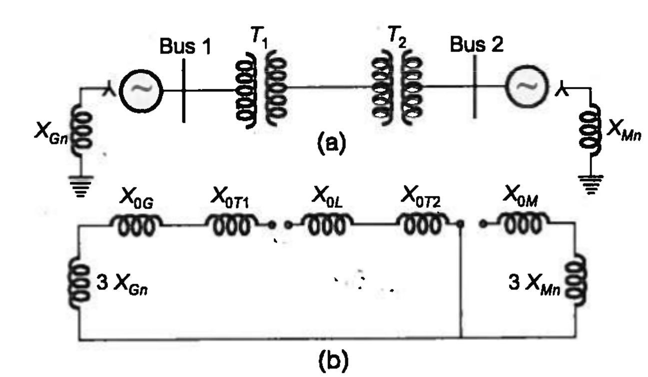


If the fault takes place at location F_1, then the voltage and the current at bus A are V_{F1} and I_{F1} respectively. If the fault takes place at location F_2, then the voltage and the current at bus A are V_{F2} and I_{F2} respectively. The correct statement about voltages and currents during faults at F_1 and F_2 is

(a) V_{F1} leads I_{F1} and V_{F2} leads I_{F2}
(b) V_{F1} leads I_{F1} and V_{F2} leads I_{F2}
(c) V_{F1} lags I_{F1} and V_{F2} leads I_{F2}
(d) V_{F1} lags I_{F1} and V_{F2} lags I_{F2}

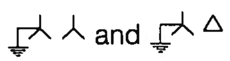
[GATE-2014]

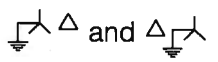
Q.36 A 2-bus system and corresponding zero sequence network are shown in the figure.

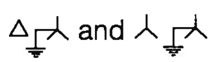


The transformer T_1 and T_2 are connected as

(a) ⅄ ⅄ and ⅄ Δ

(b) 

(c) 

(d) 

[GATE-2014]

Q.37 In an unbalanced three-phase system, phase current $I_a = 1\angle(-90°)$ pu, negative sequence current $I_{b2} = 4\angle(-150°)$ pu, zero sequence current $I_{c0} = 3\angle 90°$ pu. The magnitude of phase current I_b in pu is

(a) 1.00 (b) 7.81

(c) 11.53 (d) 13.00

[GATE-2014]

Q.38 Consider the following statements regarding the fault analysis:

1. The neutral grounding impedance Z_n appears as $3Z_n$ in zero sequence equivalent circuit.
2. For faults on transmission lines, 3-phase fault is the least severe amongst other faults.
3. The positive and negative sequence networks are not affected by method of neutral grounding.

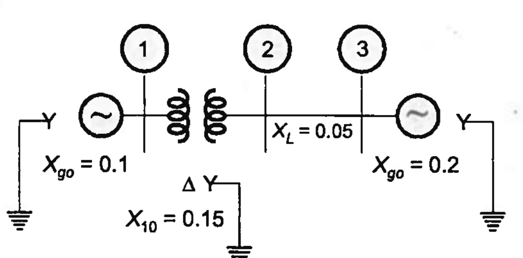
Which of these statements are correct?

(a) 2 and 3 (b) 1 and 2

(c) 1 and 3 (d) 1, 2 and 3

[ESE-2004]

Q.39 For the network shown in figure the zero sequence reactances in p.u. are indicated. The zero sequence driving point reactance of the node 3 is



(a) 0.12 p.u. (b) 0.30 p.u.

(c) 0.10 p.u. (d) 0.20 p.u.

[GATE-1998]

Numerical Data Type Questions

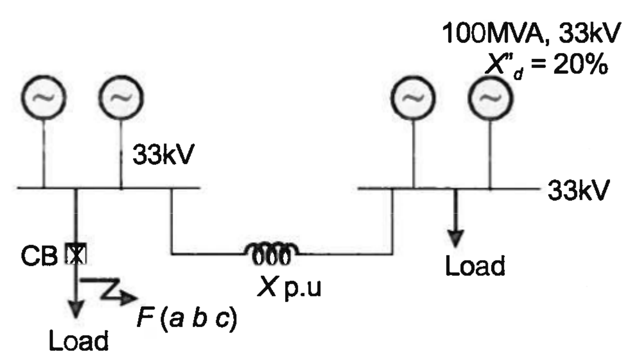
Q.40 A three-phase, 100 MVA, 25 kV generator has solidly grounded neutral. The positive, negative and the zero sequence reactances of the generator are 0.2 pu, 0.2 pu and 0.05 pu, respectively, at the machine base quantities. If a bolted single phase to ground fault occurs at the terminal of the unloaded, generator, the fault current in amperes immediately after the fault is _____.

[GATE-2014]

Q.41 The direct axis reactance X_d of a synchronous generator is given as 0.4 pu based on the generator's name plate rating of 10 kV, 75 MVA. The base for calculation is 11 kV, 100 MVA. The pu value of X_d on the new base is _____.

[ESE-2005]

Q.42 Four identical 100 MVA, 33 kV generators are operating in parallel, as shown below, in two bus-bar sections, interconnected through a current limiting reactor of X p.u. reactance on the generator-base. Each generator has a reactance of 0.2 p.u.



The value of the reactor x to limit a symmetrical short-circuit (*a-b-c*) current through the circuit breaker to 1500 MVA is _____ p.u.

[ESE-2003]

Q.43 An isolated synchronous generator with transient reactance equal to 0.1 pu on a 100 MVA base is connected to the high voltage bus through a step up transformer of reactance 0.1 pu on a 100 MVA base. The fault level at the bus is _____ MVA.

[ESE-2000]

Q.44 The severity of line-to-ground and three-phase faults at the terminals of an unloaded synchronous generator is to be same. If the terminal voltage is 1.0 p.u. and $z_1 = z_2 = j0.1$ pu, $z_0 = j0.05$ pu for the alternator, then the required inductive reactance for neutral grounding is _____ pu.

[GATE-2000]

Q.45 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 _____ kA.

[GATE-2004]

Q.46 A single-phase star connected load is drawing power at a voltage of 0.9 pu and 0.8 power factor lagging. The three-phase base power and base current are 100 MVA and 437.38 A respectively. The line-to-line load voltage in kV is _____.

[GATE-2014]

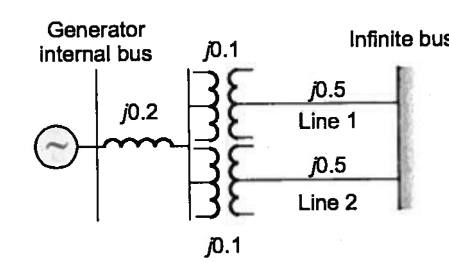
Q.47 The magnitude of three-phase fault currents at buses *A* and *B* of a power system are 10 pu and 8 pu, respectively. Neglect all resistances in the system and consider the pre-fault system to be unloaded. The pre-fault voltage at all buses in the system is 1.0 pu. The voltage magnitude at bus *B* during a three-phase fault at bus *A* is 0.8 pu. The voltage magnitude at bus *A* during a three-phase fault at bus *B*, in pu, is _________.

[GATE-2016]

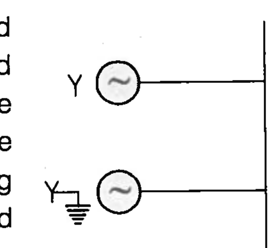
Q.48 A 30 MVA, 3-phase, 50 Hz, 13.8 kV, star-connected synchronous generator has positive, negative and zero sequence reactances, 15%, 15% and 5% respectively. A reactance (X_n) is connected between the neutral of the generator and ground. A double line to ground fault takes place involving phases '*b*' and '*c*', with a fault impedance of j0.1 p.u. The value of X_n (in p.u.) that will limit the positive sequence generator current to 4270 A is _________.

[GATE-2016]

Q.49 The single line diagram of a balanced power system is shown in the figure. The voltage magnitude at the generator internal bus is constant and 1.0 p.u. The p.u. reactances of different components in the system are also shown in the figure. The infinite bus voltage magnitude is 1.0 p.u. A three phase fault occurs at the middle of line 2. The ratio of the maximum real power that can be transferred during the pre-fault condition to the maximum real power that can be transferred under the faulted condition is ________.



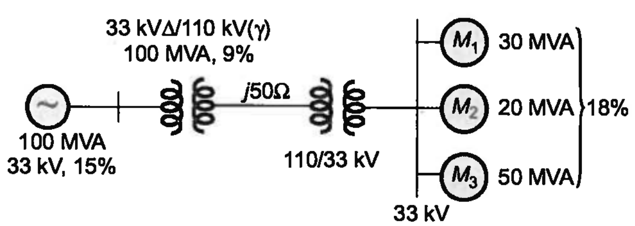
Q.50 Two identical unloaded generators are connected in parallel as shown in the figure. Both the generators are having positive, negative and zero sequence impedance of $j0.4$ p.u, $j0.3$, p.u. and $j0.15$ p.u., respectively. If the pre-fault voltage is 1 p.u., for a line-to-ground (L-G) fault at the terminals of the generators, the fault current, in p.u., is________.



[GATE-2016]

Conventional Questions

Q.51 A 100 MVA, 33 kV, 3-phase generator has a substransient reactance of 15%. The generator is connected to the motors through transmission line and transformers as shown in figure given below. The motors have rated inputs of 30 MVA, 20 MVA and 50 MVA at 30 kV with 18% substransient reactance. The three phase transformers are rated at 100 MVA, 33 kV(Δ)/ 110 kV(λ) with leakage reactance of 9%. The line has a reactance of 50 ohms. Selecting the generator ratings as base quantities. Obtain the p.u. reactance diagram of the system.



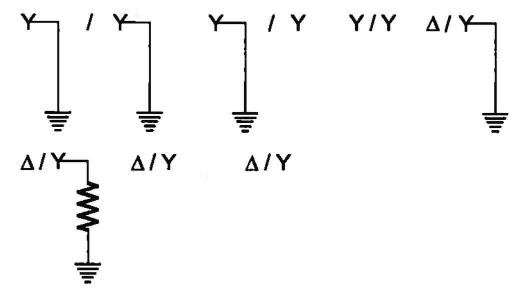
[ESE-2001]

Q.52 Two 11 kV, 20 MVA, three phase, star connected generators operate in parallel. The positive, negative and zero sequence reactances of each being respectively $j0.18$, $j0.15$, $j0.10$ p.u. The star point of one of the generator is isolated and that of the other is earthed through a 2 Ω resistor. A single line-to-ground fault occurs at the terminals of one of the generators.

Estimate:
(a) the fault current
(b) current in grounding resistor and
(c) voltage across the grounding resistor

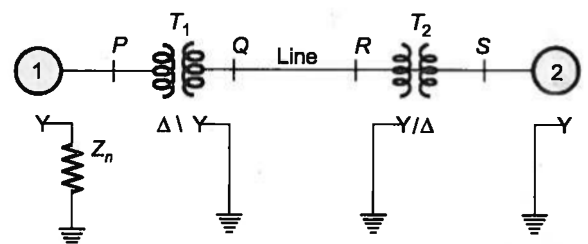
[ESE-2004]

Q.53 Draw the positive sequence, negative sequence and zero sequence Impedance networks for the below 3 phase transformer connections.



[ESE-2007]

Q.54 One-line diagram of a small power system is given below. Draw the zero-sequence network.



The zero-sequence reactances of the various components are denoted as follows:
Generator 1 = X_{10}; Line = X_{L0}; Generator 2 = X_{20}; Transformer $T_1 = X_{t10}$; Transformer $T_2 = X_{t20}$

[ESE-2009]

Q.55 Determine the magnitudes of the symmetrical components (I_{R1}, I_{R2} and I_{R0}) of the currents in a 3-phase (RYB) three wire system, when a short circuit occurs between *R* and *Y* phase wires, the fault current being 100 A.

[GATE-1999]

4.3 - Stability Studies

Multiple Choice Questions

Q.56 Match **List-I (Phenomenon)** with **List-II (Dominant features)** and select the correct answer using the codes given below the lists:

List-I
A. Voltage stability
B. Tansient stability
C. Oscillatory instability
D. Steady-state Dynamics

List-II
1. Power system stabilizer
2. Damping power
3. 'Angle' stability
4. Reactive power

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	4	2	3	1
(c)	1	2	3	4
(d)	4	3	2	1

[ESE-2002]

Q.57 The inertia constant of a 100 MVA, 50 Hz, 4-pole generator is 10 MJ/MVA. If the mechanical input to the machine is suddenly raised from 50 MW to 75 MW, the rotor acceleration will be equal to
(a) 225 electrical degree/s^2
(b) 22.5 electrical degree/s^2
(c) 125 electrical degree/s^2
(d) 12.5 electrical degree/s^2

Q.58 An alternator having an induced e.m.f. of 1.6 p.u. is connected to an infinite bus of 1.0 p.u. If the bus bar has reactance of 0.6 p.u. and alternator has reactance of 0.2 p.u., what is the maximum power that can be transferred?
(a) 2 p.u. (b) 2.67 p.u.
(c) 5 p.u. (d) 6 p.u.

[ESE-2007]

Q.59 A round rotor generator with internal voltage $E_1 = 2.0$ p.u. and $X = 1.1$ p.u. is connected to a round rotor synchronous motor with internal voltage $E_2 = 1.3$ p.u. and $X = 1.2$ p.u. The reactance of the line connecting the generator to the motor is 0.5 p.u. When the generator supplies 0.5 p.u. power, the rotor angle difference between the machines will be
(a) 57.42° (b) 1°
(c) 32.58° (d) 122.58°

[GATE-2003]

Q.60 Consider the following statements:
Stability studies constitute
1. the major analytical approach to the study of power system electromechanical dynamic behaviour.
2. the involvement of one or just a few machines undergoing slow or gradual changes in operating conditions.
3. the determination of the locus of essentially steady-state operating points of the system.
4. the determination of whether or not the rotors of the machines being perturbed, return to the constant speed operation.

Which of the statements given above are correct?
(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1 and 4 (d) 1, 2, 3 and 4

[ESE-2004]

Q.61 The 'Equal area criterion' for the determination of transient stability of the synchronous machine connected to an infinite bus
(a) Ignores line as well as synchronous machine resistances and shunt capacitances
(b) Assume accelerating power acting on the rotor as constant
(c) Ignores the effect of voltage regulator and governor but considers the inherent damping present in the machine
(d) Takes into consideration the possibility of machine loosing synchronism after it has survived during the first swing

[ESE-2011]

Q.62 Consider the following statements:
The transient stability of the power system under unbalanced fault conditions can be effectively improved by
1. Excitation control.
2. Phase-shifting transformer.
3. Single-pole switching of circuit breakers.
4. Increasing the turbine input.

Of these statements:
(a) 1 and 2 are correct
(b) 2 and 3 are correct
(c) 3 and 4 are correct
(d) 1 and 3 are correct

[ESE-1998]

Q.63 Equal area criterion gives the information regarding

(a) stability region (b) absolute stability

(c) relative stability (d) swing curves

[ESE-1998]

Q.64 Figure-2 given below is the "equal-area" criterion diagram for the determination of transient stability limit of the power system shown in figure 1 for a fault on the transmission line.

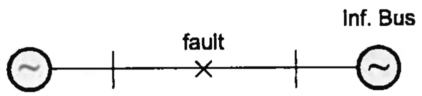


Figure 1

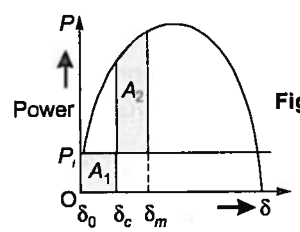


Figure 2

(a) Three phase fault with instantaneous clearing

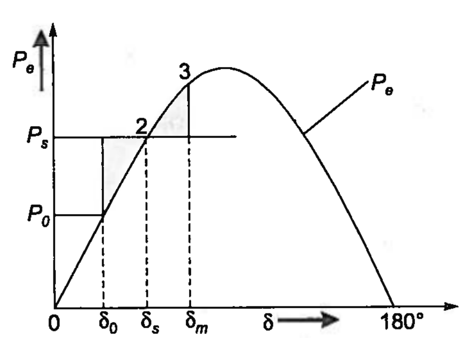
(b) Three phase fault with subsequent clearing

(c) Single-line to ground fault with instantaneous clearing

(d) Single-line to ground fault with subsequent clearing

[ESE-2007]

Q.65 The figure given shows electric power input P_e to a lossless synchronous motor as a function of torque angle δ. The load is suddenly increased from P_0 to P_s and the motor oscillates around $d\delta$ between δ_0 and δ_m.



Consider the following statements derived from the figure regarding the relationship between the motor speed ω and its synchronous speed ω_s at different points in the oscillating cycle:

(*i*) At point 1, $\omega = \omega_s$.

(*ii*) At point 2, while oscillating from 1 towards 3, $\omega > \omega_s$

(*iii*) At point 3, $\omega < \omega_s$.

(*iv*) At point 2, while oscillating from 3 towards 1, $\omega > \omega_s$

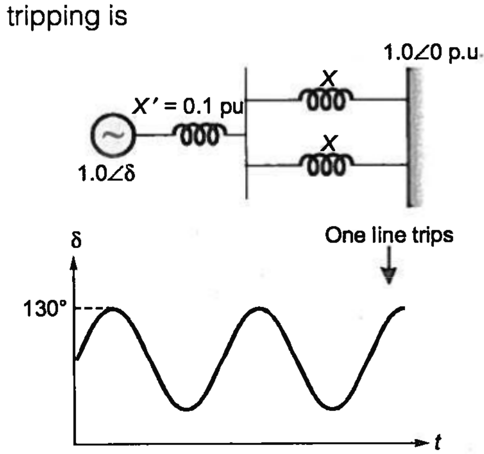
Which of these statement(s) is/are correct?

(a) (*i*) and (*iv*) (b) (*i*), (*ii*) and (*iv*)

(c) (*i*) and (*iii*) (d) (*iii*) alone

[IAS-2001]

Q.66 Consider a synchronous generator connected to an infinite bus by two identical parallel transmission lines. 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 relay maloperation at an instant when $\delta(t)$ = 130° 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

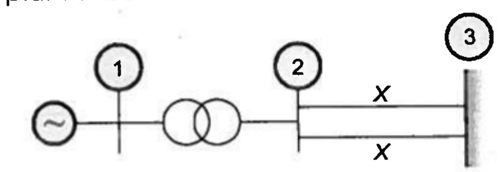


(a) 0.87 (b) 0.74

(c) 0.67 (d) 0.54

[GATE-2007]

Q.67 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 susceptances 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, the 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.

[GATE-2005]

Q.68 A 50 Hz, 4-pole, 500 MVA, 22 kV turbo-generator is delivering rated MVA at 0.8 power factor. Suddenly a fault occurs reducing electric power output by 40%. Neglect losses and assume constant power input to the shaft. The accelerating torque in the generator in MN-m at the time of the fault will be

(a) 1.528 (b) 1.018

(c) 0.848 (d) 0.509

[GATE-2004]

Q.69 During a disturbance on a synchronous machine, the rotor swings from *A* to *B* before finally settling down to a steady state at point *C* on the power angle curve. The speed of the machine during oscillation is synchronous at point(s)

(a) *A* and *B* (b) *A* and *C*

(c) *B* and *C* (d) only at *C*

[GATE-1997]

Q.70 The use of fast acting relays and circuit breakers for clearing a sudden short-circuit on a transmission link between a generator and the receiving-end bus improves the transient stability of the machine because the

(a) short-circuit current becomes zero

(b) post-fault transfer impedance attains a value higher than that during the fault

(c) ordinate of the post-fault power-angle characteristic is higher than that of during-fault characteristic

(d) voltage behind the transient reactance increases to a higher value

[ESE-1998]

Q.71 Steady-state stability of a power system is improved by

(a) reducing fault clearing time

(b) using double circuit line instead of single circuit line

(c) single pole switching

(d) decreasing generator inertia

[ESE-1998]

Statement for Common Data Questions (72 and 73):

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.

Q.72 The initial accelerating power (in pu) will be

(a) 1.0 (b) 0.6

(c) 0.56 (d) 0.4

[GATE-2006]

Q.73 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) 31.4 X, 18 (b) 1800 X, 0.056

(c) X/1800, 0.056 (d) X/31.4, 18

[GATE-2006]

Q.74 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 δ_{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

[GATE-2003]

Q.75 Two 50 Hz generating units operate in parallel within the same power plant and have the following ratings:

Unit 1 : 500 MVA, 0.85 power factor, 20 kV, 3000 rpm,

H_1 = 5 MJ/MVA

Unit 2 : 200 MVA, 0.9 power factor, 20 kV, 1500 rpm,

H_2 = 5 MJ/MVA.

The equivalent inertia constant H in MJ/MVA on 100 MVA base is

(a) 2.5 (b) 5.0
(c) 10.0 (d) 35.0

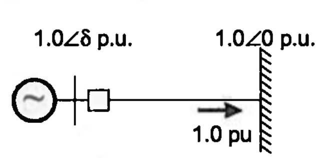
[ESE-2001]

Q.76 The steady state stability limits for round rotor and salient pole 3-phase synchronous generator are attained at the values of power angle δ

(a) = π/2 and = π/2, respectively
(b) < π/2 and < π/2, respectively
(c) < π/2, and = π/2, respectively
(d) = π/2, and < π/2, respectively

[ESE-2006]

Q.77 A lossless 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

[GATE-2008]

Numerical Data Type Questions

Q.78 A synchronous generator is connected to an infinite bus with excitation voltage E_f = 1.3 pu. The generator has a synchronous reactance of 1.1 pu and is delivering real power (P) of 0.6 pu to the bus. Assume the infinite bus voltage to be 1.0 pu. Neglect stator resistance. The reactive power (Q) in pu supplied by the generator to the bus under this condition is ________ .

[GATE-2014]

Q.79 There are two generators in a power system. No load frequencies of the generators are 51.5 Hz and 51 Hz, respectively, and both are having droop constant of 1 Hz/MW. Total load in the system is 2.5 MW. Assuming that the generators are operating under their respective droop characteristics, the frequency of the power system in Hz in the steady state is _____.

[GATE-2014]

Q.80 A cylindrical 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 _____.

[GATE-2012]

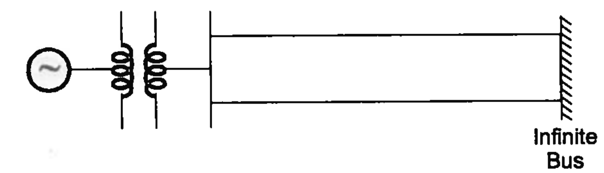
Q.81 If a generator of 250 MVA rating has an inertia constant of 6 MJ/MVA, its inertia constant on 100 MVA base is _____ MJ/MVA.

[ESE-2000]

Q.82 If the inertia constant H = 8 MJ/MVA for a 50 MVA generator, the stored energy is __ MJ.

[ESE-2011]

Q.83 The figure shows the single line diagram of a single machine infinite bus system.



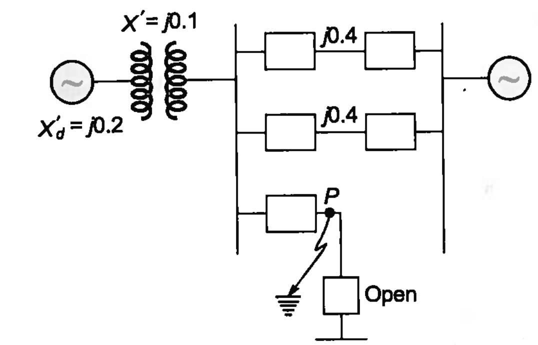
The inertia constant of the synchronous generator H = 5 MW-s/MVA. Frequency is 50 Hz. Mechanical power is 1 pu. The system is operating at the stable equilibrium point with rotor angle δ equal to 30°. A three-phase short-circuit fault occurs at a certain location on one of the circuits of the double circuit transmission line. During fault, electrical power in pu is P_{max} sin δ. If the values of δ and $d\delta/dt$ at the instant of fault clearing are 45° and 3.762 radian/s respectively, then P_{max} (in pu) is _____ .

[GATE-2014]

Q.84 A system consisting of a generator of equivalent reactance 1.0 pu connected to an infinite bus through a series reactance of 0.6 pu. The terminal voltage of the generator (E_g) is held at 1.0 pu and the voltage of the infinite bus at 1.0 pu. The steady state limit of the system is_____ pu.

Q.85 In the system shown below, the generator is delivering 1 pu power. The voltage behind transient reactance is 1.05 pu and infinite bus voltage is 1 pu. The number on the diagram are the pu reactance on a common system bus. If the system is subjected to a 3-ϕ fault on point P, the critical clearing angle is ____ electrical degrees.

[Take H = 5 MJ/MVA and f = 50 Hz]



Q.86 A synchronous generator of reactance 1.20 pu is connected to an infinite bus bar ($|V|$ = 1.0 pu) through transformer and a line of total reactance of 0.60 pu. The generator no load voltage is 1.20 pu and its inertia constant is H = 4 MW-s/MVA. The resistance and machine damping may be assumed negligible. The system frequency is 50 Hz.

The frequency of natural oscillations if the generator is loaded to 50% of its maximum power limit is ______ Hz.

Conventional Questions

Q.87 A 50 Hz two pole turbo alternator rated 50 MVA, 13.2 kV has an inertia constant H = 5.0 MJ/MVA. Determine the kinetic energy stored in the rotor at synchronous speed. Determine the acceleration if the input less the rotational losses is 65000 HP and the electrical power developed is 40 MW. If the acceleration computed for the generator is constant for a period of 10 cycles, determine the change in torque angle in that period and the r.p.m. at the end of 10 cycles. Assume that the generator is synchronised with a large system and has no accelerating torque before the 10 cycles period begins.

[ESE-2005]

Q.88 A two-machine power system delivers a load of 25 MW at 0.8 p.f. lag and has a double circuit. The system reactance is 150 percent on 100 MVA base. A sudden symmetrical line-to-ground fault occurs in one of the circuits which reduced the power supplied to 40% which is subsequently cleared by simultaneous action of the circuit breakers on both sides of the faulted line. Calculate in the electrical degrees the "critical clearing angle". Assume that during fault conditions the system reactance attains such a value that the maximum power becomes 30% of the normal maximum value, when the faulty line is isolated the maximum power of the system is 60% of the normal maximum power.

[ESE-2006]

Q.89 A 50 Hz synchronous generator is connected to an infinite bus through a line. The p.u. reactances of the generator and the line are $j0.3$ p.u. and $j0.2$ p.u. respectively. The generator no load voltage is 1.1 p.u. and that of the infinite Bus is 1.0 p.u. The inertia constant of the generator is 3 MW-sec/MVA.

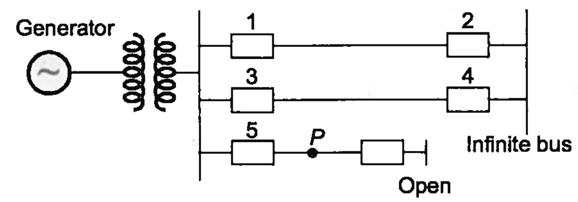
(a) If the generator is loaded to 60% of its maximum power transfer capacity and small perturbation is given, calculate resulting natural frequency of oscillations.

(b) If the generator is loaded to 75% of its maximum power transfer capacity and a small perturbation is given, calculate the new natural frequency of oscillations.

[ESE-2007]

Q.90 Define and derive swing equation for a finite machine connected to an infinite bus. Discuss the applications in the study of power system stability. [ESE-2008]

Q.91 The single line diagram of a three-phase power system is given below. The generator is delivering 1.0 per unit power to the infinite bus. The pre-fault power angle equation is $P_e = 2.10 \sin\delta$.
Calculate the critical clearing angle and critical clearing time when the system is subjected to a 3-phase fault at point P (*i.e.* sending end of the short-line). The fault is cleared by opening the circuit breaker 5. The inertia constant $H = 50$ MJ/MVA.



[ESE-2010]

Q.92 A 500 MVA, 20 kV, 60 Hz, 4-pole synchronous generator is connected to an infinite bus through a purely reactive network. The generator has an inertia constant $H = 60$ MJ/MVA and is delivering power of 1.0 pu to the infinite bus at steady state. The maximum power that can be delivered is 2.5 p.u. A fault occurs that reduces the generator output to zero. Determine the

(*i*) angular acceleration

(*ii*) speed in rpm at the end of 15 cycles.

[ESE-2014]

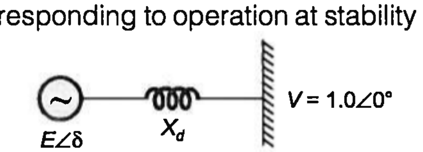
Q.93 Using equal area criterion, derive the expression for critical clearing angle for a system having a generator feeding a large system through a double circuit transmission line.

[ESE-2001]

Q.94 A large generator is delivering 1.0 p.u. power to an infinite bus through a transmission network. The maximum powers which can be transferred for pre-fault, fault and post-fault conditions are 1.8 p.u., 0.4 p.u. and 1.3 p.u. respectively. Find critical clearing angle.

[ESE-2001]

Q.95 An alternator is connected to an infinite bus as shown in figure. It delivers 1.0 p.u. current at 0.8 p.f. lagging at $V = 1.0$ p.u. The reactance X_d of the alternator is 1.2 p.u. Determine the active power output and the steady state power limit. Keeping the active power fixed, if the excitation is reduced, find the critical excitation corresponding to operation at stability limit.



[GATE-1998]

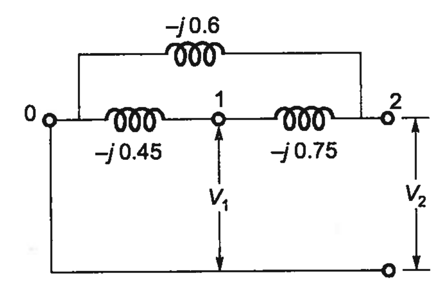
Try Yourself

T1. A 12 bus power system has three voltage controlled buses. The dimension of the Jacobian matrix will be

(a) 16 × 16 (b) 21 × 21
(c) 19 × 19 (d) 19 × 21

[Ans: (c)]

T2. The Y_{BUS} matrix for the power network given below is



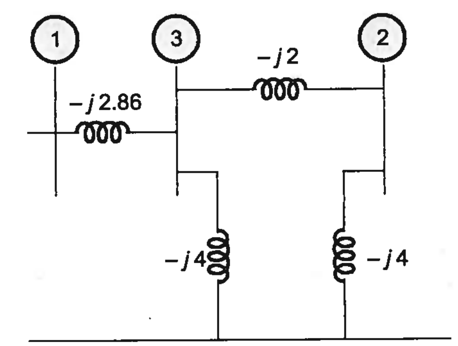
The relevant pu line admittances are indicated on the diagram

(a) $\begin{bmatrix} j0.46 & j0.24 \\ j0.24 & -j0.21 \end{bmatrix}$ (b) $\begin{bmatrix} -j1.2 & j0.75 \\ j0.75 & -j1.35 \end{bmatrix}$

(c) $\begin{bmatrix} j1.2 & j0.46 \\ j0.46 & j1.35 \end{bmatrix}$ (d) $\begin{bmatrix} -j1.2 & j0.2 \\ j0.2 & -j1.35 \end{bmatrix}$

[Ans: (b)]

T3. In the system shown below,



the Y_{Bus} matrix is,

(a) $j\begin{bmatrix} 2.86 & 4 & 2 \\ 2 & -4 & 2.2 \\ 4 & 2.2 & 8.86 \end{bmatrix}$

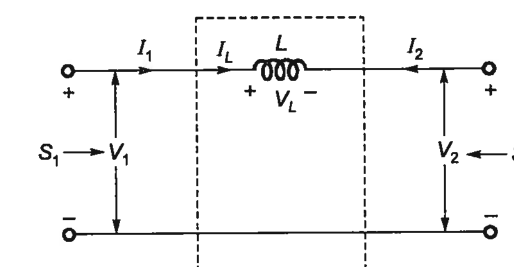
(b) $j\begin{bmatrix} -2.86 & 0 & 2.2 \\ 0 & -4 & 4 \\ 2.2 & 4 & -8.86 \end{bmatrix}$

(c) $j\begin{bmatrix} -2.86 & 0 & 2.86 \\ 0 & -6 & 2 \\ 2.86 & 2 & -8.86 \end{bmatrix}$

(d) $j\begin{bmatrix} 2.86 & -4 & 2 \\ -4 & 2 & 0 \\ 4 & 0 & 8.66 \end{bmatrix}$

[Ans: (c)]

T4. In the lossless line shown in figure, show that $S_2 = -S_1^*$ if the magnitudes of the two voltages are same. Interpret the result.



T5. A 3-phase, 50 Hz generator is rated at 500 MVA, 20 kV with $X_d'' = 0.2$ pu. It supplies pure resistive load of 400 MW at 20 kV. The load is connected directly across the terminals of the generator. If all the three phases of the load are short circuited simultaneously, then the initial symmetrical rms current in the generator in per unit on a base of 500 MVA, 20 kV is

(a) 2.24 pu (b) 4.23 pu
(c) 3.43 pu (d) 5.06 pu

[Ans: (d)]

T6. A 10 MVA, 13.8 kV alternator has positive, negative and zero sequence reactances of 30%, 40% and 5% respectively.
The value of resistance that must be placed in the generator neutral so that the fault current for a line to ground fault of zero fault impedance will not exceed the rated line current is

(a) 16.12 Ω (b) 18.43 Ω
(c) 17.16 Ω (d) 20.24 Ω

[Ans: (b)]

T7. When a fault occurs in a power system the following sequence currents are recorded.

$I_{Zero} = -j\,1.246$ pu

$I_{Positive} = -j\,1.923$ pu

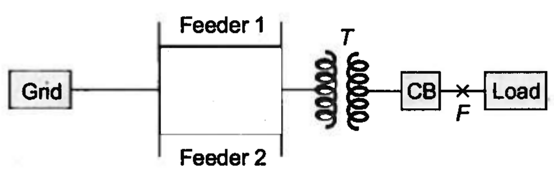
$I_{Negative} = -j\,0.8$ pu

The fault is

(a) line to ground
(b) line to line
(c) line to line to ground
(d) three-phase

[Ans: (c)]

T8. In the system shown below consider the grid as infinite bus. Choose 6 MVA as base.



Transformer : 3-phase, 33/11 kV, 6 MVA, $0.01 + j\,0.08$ pu impedance.

Load : 3-phase, 11 kV, 5,800 kVA, 0.8 lag, $j\,0.2$ pu impedance.

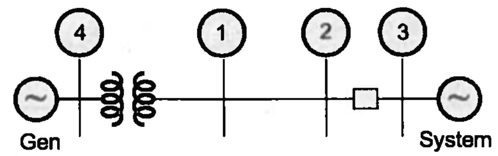
Impedance of each feeder : $9 + j\,18\ \Omega$

The required MVA rating of the circuit breaker CB is

(a) 41.26 MVA (b) 56.12 MVA
(c) 44.72 MVA (d) 52.24 MVA

[Ans: (a)]

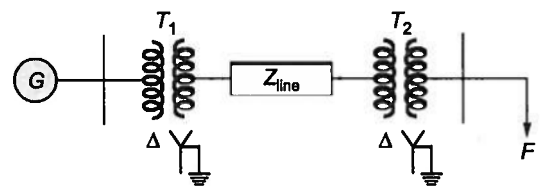
T9. For the configuration shown in figure the breaker connecting a large system to bus 2 is initially open. The system 3-phase fault level at bus 3 under this condition is not known. After closing the system breaker, the 3-phase fault level at bus 1 was found to be 5.0 p.u. What will be the new 3-phase fault level at system bus 3 after the interconnection? All per unit values are on common base. Prefault load currents are neglected and prefault voltages are assumed to be 1.0 p.u. at all buses.



$E_g = 1.0$ p.u., $X_T = 0.2$ p.u., $X_{Line} = 0.3$ p.u., $X_d'' = 0.2$ p.u.

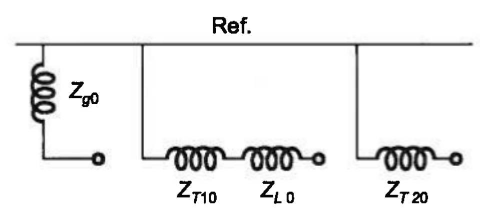
[GATE-2000]

T10. The one line diagram of a system is shown in figure.

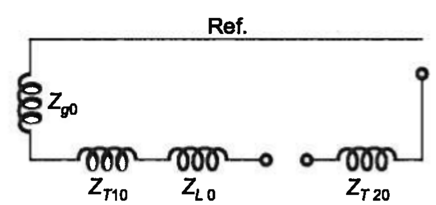


The zero sequence network is

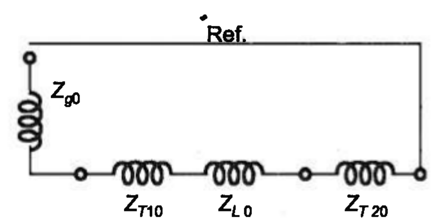
(a)



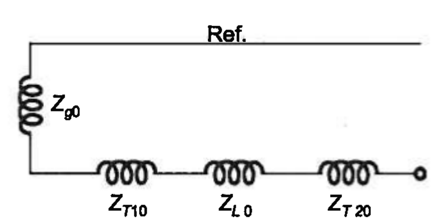
(b)



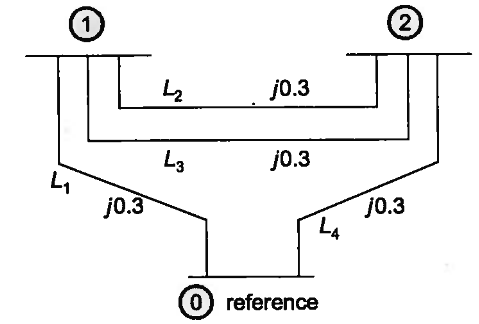
(c)



(d)



T11. In the system shown below, the Z_{bus} of the network is $\begin{bmatrix} j0.18 & j0.12 \\ j0.12 & j0.18 \end{bmatrix}$

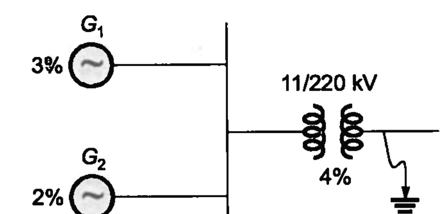


If line L_2 between the buses 1 and 2 is removed, then the modified Z_{bus} is

(a) $\begin{bmatrix} -j0.2 & j0.1 \\ j0.1 & -j0.2 \end{bmatrix}$ (b) $\begin{bmatrix} j0.2 & j0.1 \\ j0.1 & j0.2 \end{bmatrix}$

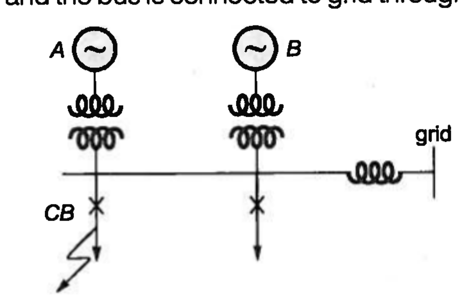
(c) $\begin{bmatrix} j0.1 & j0.2 \\ j0.2 & j0.1 \end{bmatrix}$ (d) $\begin{bmatrix} -j0.1 & j0.2 \\ j0.2 & -j0.1 \end{bmatrix}$

T12. Two 11 kV, 3-phase, 5 MVA generator having subtransient reactance of 3% and 2% respectively operate in parallel. Suppose the power loaded through a 11/220 kV, 10 MVA transformer has % equivalent reactance of 4%. The fault current of generator 1 if a three phase fault occurs at H.T. side of the transformer is



(a) 3.28 KA (b) 4.92 KA
(c) 8.2 KA (d) 5.66 KA

T13. Alternators 10 MVA, 11 kV having 8% reactance and transformer 15 MVA, 11/33 kV having 10% reactance are connected to bus as shown below and the bus is connected to grid through reactor.



What is the value of reactor reactance if fault occurs on feeder and current to be limited to CB rating of 500 MVA? (Take 15 MVA as base)

(a) 0.041 pu (b) 0.045 pu
(c) 0.128 pu (d) 0.09 pu

T14. Which of the following statements is incorrect?

(a) The inertia constant of an alternator is the ratio of the stored energy in MJ to its machine rating MVA.

(b) The angular momentum M of a machine is $\dfrac{GH}{180f}$ MJs per electrical degree.

(c) For moment of inertia J in kg.m^2, the swing equation is $J\dfrac{d^2\delta}{dt^2} = P_S - P_E$.

(d) For the transient stability of the power system the necessary condition is $\dfrac{d\delta}{dt} = 0$ and $\dfrac{dp}{dt} > 0$

[Ans: (c)]

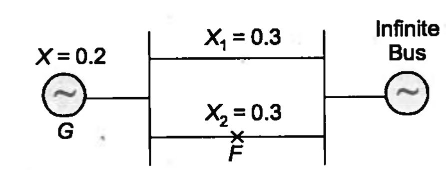
T15. A 100 MVA synchronous generator operates on full load at a frequency of 50 Hz. The load is suddenly reduced to 50 MW. Due to time lag in governor system, the steam valve begins to close after 0.4 second. The change in frequency that occurs in this time will be

[$H = 5$ kW-s/KVA of generator capacity]

(a) 1 Hz (b) 2 Hz
(c) 4 Hz (d) 5 Hz

[Ans: (a)]

T16. A 3-ϕ fault occurs at middle point F on the transmission line as shown below.



The transfer reactance between generator and infinite bus is

(a) $j0.7$ pu (b) $j0.8$ pu
(c) $j0.9$ pu (d) $j1.0$ pu

[Ans: (c)]

T17. A generator operating at 50 Hz delivers 1 pu power to an infinite bus through a transmission circuit in which resistance is ignored. A fault takes place reducing the maximum power transferable to 0.5 pu. Where as before the fault, this power was 2.0 pu and after the clearance of the fault, it is 1.5 pu. The critical clearing angle is ________.

(a) 55.5° (b) 70.3°
(c) 60.6° (d) 80.2°

[Ans: (d)]

T18. For a two machine system with losses, with the transfer impedance being resistive, the maximum value of the sending end power $P_{1\,max}$ and the maximum receiving end power $P_{2\,max}$ will occur at power angles (δ) in such a manner that

(a) Both $P_{1\,max}$ and $P_{2\,max}$ occur at $\delta < 90°$
(b) Both $P_{1\,max}$ and $P_{2\,max}$ occur at $\delta > 90°$
(c) $P_{1\,max}$ occur at $\delta > 90°$ and $P_{2\,max}$ at $\delta < 90°$
(d) $P_{1\,max}$ occur at $\delta < 90°$ and $P_{2\,max}$ at $\delta > 90°$

[Ans: (b)]

T19. The kinetic energy stored in the rotor of a 50 MVA, six pole, 60 Hz synchronous machine is 200 MJ. The input to the machine is 25 MW at a developed power of 22.5 MW. Calculate the accelerating power and the acceleration.

[Ans. (2.5 MW, 2.356 rad/s^2)]

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