# UNIT – I INTRODUCTION

## PART – A

**1. What is the advantage of per unit method over percentage method? (May 2017, Nov 2020)**

The per unit method has an advantage over the percent method because the product of two quantities expressed in per unit is expressed in per unit itself, but the product of two quantities expressed in percent must be divided by 100 to obtain result in percent.

**2. What is the need for base values? (Nov/Dec 2018, Apr/May 2018)**

The components or various sections of power system may operate at different voltage and power levels. It will be convenient for analysis of power system if the voltage, power, current and impedance ratings of components of power system are expressed with reference to a common value called base value. Hence for analysis purpose, a base value is chosen for voltage, power, current and impedance ratings of the components are expressed as a percent of per unit of the base value.

**3. Mention the requirements of planning the operation of a power system. (May 2018). (or) What are the needs of power system planning (Nov/Dec 2019) (Nov/Dec 2020)**

To utilize the existing capacity in the best possible manner is of prime importance and is particularly relevant in a developing economy. The steps taken in the method of power system planning studies are,

1.Forecast of annual energy and power demand, 2. Load modeling 3. Generation and choice of mixing the various types of generating station. 4.Optimization of power plant characteristics 5. New substations and their capacity and location 6. New power plants and their subdivision in the main areas 7. Network expansion 8. Optimization of equipment characteristics.

**4. What is single line diagram? (Nov 2015 & May 2016)**

A single line diagram is diagrammatic representation of power system in which the components are represented by their symbols and the inter connection between them are shown by a single straight line (even though the system is 3-phase system). The ratings and the impedances of the components are also marked on the single line diagram.

**5. What are the components of power system? (May 2012)**

The components of power system are generators, power transformers, motors, transmission lines, substation transformers, distribution transformers and loads.

**6. Define per unit value of an electrical quantity and write the equation for base impedance for a three phase power system. (Dec 2017) (Nov 2015)**

Per unit value of any quantity is defined as the ratio of actual quantity to its base quantity expressed an a decimal.

$$\text{Per unit value} = \frac{\text{Actual value}}{\text{Base value}}$$

The equation for base impedance for a three phase power system is given as, Base impedance $Z_b = kV_b^2/MVA_b$

**7. Write the equation for converting the p.u. impedance expressed in one base to another?(May 2016, Dec 2017)**

$$Z_{pu,New} = Z_{pu,old} X \left[\frac{KV_{b,old}}{KV_{b,new}}\right]^2 X \left[\frac{MVA_{b,new}}{MVA_{b,old}}\right]$$

**8. What are the advantages (needs) of per unit computation? (Nov 2014, Nov 2016)**

i) Manufactures usually specify the impedance of a device or machine in per unit on the base of the name plate rating. ii) The p.u. values of widely different rating machines lie within a narrow range, even though the ohmic values has a very large range.iii) The p.u. Impedance of circuit element connected by transformers expressed on a power base will be same is if it is referred to either side of a transformer. iv) The p.u. impedance of a 3$\phi$ transformer is independent of the type of winding connection (Y or $\Delta$)

**9. How the loads are represented in reactance or impedance diagram? (Nov 2016, Nov 2020)**

The resistive and reactive loads can be represented by any one of the following representation.

i) Constant power representation, Load power $S = P + jQ$

ii) Constant current representation, Load Current $I = \sqrt{\frac{P^2+Q^2}{|V|}}\angle\delta - \theta$

iii) Constant impedance representation. Load impedance $Z = \frac{V^2}{P-jQ}$

**10. A generator rated at 30MVA, 11KV has a reactance of 20% calculate its p.u reactance for a base of 50 MVA and 10KV.**

$X_{pu,new} = X_{pu} = 0.2 \times (11/10)^2 \times (50/30) = 0.403$pu

**11. The base KV and base MVA of a 3-phase transmission line is 33KV and 10 MVA respectively calculate the base current and base impedance?**

Base current, $I_b = \frac{(KVA)_b}{\sqrt{3}KV_b} = \frac{(MVA)_b \times 1000}{\sqrt{3}KV_b} = \frac{10 \times 1000}{\sqrt{3} \times 33} = 175A$

Base impedance, $Z_b = \frac{(KV_b)^2}{MVA_b} = \frac{33^2}{10} =$ 108.9Ω

**12. What is impedance diagram? (April 2019)**

The impedance diagram is the equivalent circuit of power system in which the various components of power system are represented by their approximate or simplified equivalent circuits. The impedance diagram is used for load flow studies.

**13. What is reactance diagram?**

The reactance diagram is the simplified equivalent circuit of power system in which the various components are represented by their reactance. The reactance diagram can be obtained from impedance diagram if all the resistive components are neglected. The reactance diagram is used for fault calculations.

**14. What are the approximations made in impedance diagram? (Nov/Dec 2018, April 2019).**

i) The neutral reactance are neglected ii) Shunt branches in the equivalent circuits of transformers are neglected iii) The resistance are neglected. iv) All static loads and induction motors are neglected. v) the capacitance of the transmission lines are neglected

**15. Give equations for transforming base KV on LV side to HV side of transformer.**

$$\text{Base KV on HT side} = \text{Base KV on LT side X } \frac{\text{HT voltage rating}}{\text{LT voltage rating}}$$

$$\text{Base KV on LT side} = \text{Base KV on HT side X } \frac{\text{LT voltage rating}}{\text{HT voltage rating}}$$

LT - Low Tension or Low Voltage

HT- High Tension or High Voltage

**16. What is bus?**

The meeting point of various components in a power system is called as bus. The bus is a conductor made of copper or aluminum having negligible resistance. The buses are considered as points of constant voltage in a power system.

**17. What are the disadvantages of per unit system?**

The disadvantages of per unit system are some equations that hold in the unscaled case are modified when scaled into per unit factors such as √3 and 3 are removed or added in this method. Equivalent circuits of the components are modified making them somewhat more abstract. Sometimes these shifts that are clearly present in the unscaled circuit vanish in per unit circuit.

**18.Write the four ways of adding an impedance to an existing system so as to modify $Z_{Bus}$ matrix. (April 2019).**

1. Adding a branch of impedance $Z_b$ from a new bus p to the reference bus. 2. Adding a branch of impedance $Z_b$ from a new bus p to an existing bus. 3. Adding a branch of impedance $Z_b$ from an existing bus q to the reference bus. 4. Adding a branch of impedance $Z_b$ between two existing buses p and q.

**19. What are the methods available for forming bus impedance matrix?**

(i) Form the bus impedance matrix and then take its inverse to get bus impedance matrix.

(ii) Directly from the bus impedance matrix from the reactance diagram. This method utilizes the techniques of modifications of existing bus impedance matrix due to addition of new bus.

**20. What are the representations of loads? (May 2014)**

i) Constant power representation

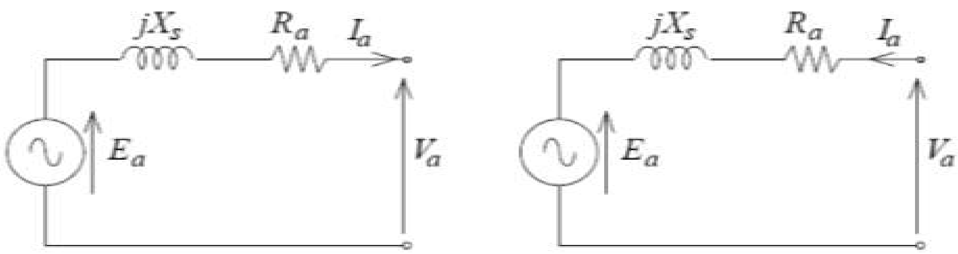
ii) Constant current representation

iii) Constant impedance representation

**21. What are the advantages of per unit system? (May 2011)**

a) Calculations are simple. b) It will be convenient for analysis of power system if the voltage, power, current and impedance ratings of components of power system are expressed with reference to a common value called base value

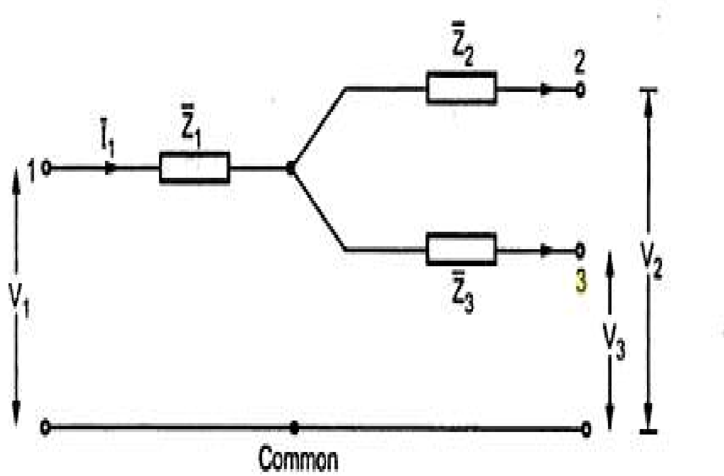
**22. Draw a simple per-phase model for a cylindrical rotor synchronous machine. (May 2011)**




**23. If the reactance in ohms is 15, find the p.u value for a base of 15KVA and 10KV? (May 2012)**

$$Z(pu) = \frac{Z \times MVA_b}{KV_b^2} = \frac{15 \times 15}{10^2} = 2.25$$

**24. Draw the equivalent circuit of a three winding transformer. (Nov 2012, May 2013)**




**25. What is meant by percentage reactance? (May 2013)**

Percentage reactance of a transformer (or in general, a circuit) is the percentage of phase voltage drop when full load current flows through it, i.e %X= (I X / V)*100.

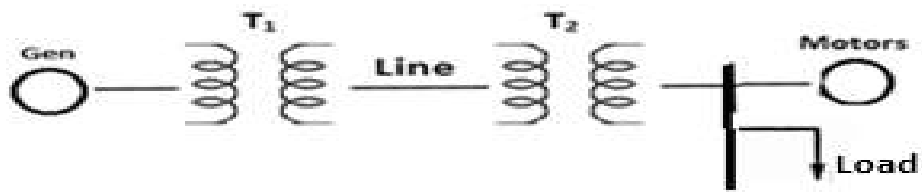
**26. What are the functions of Modern power system? (Nov 2013)**

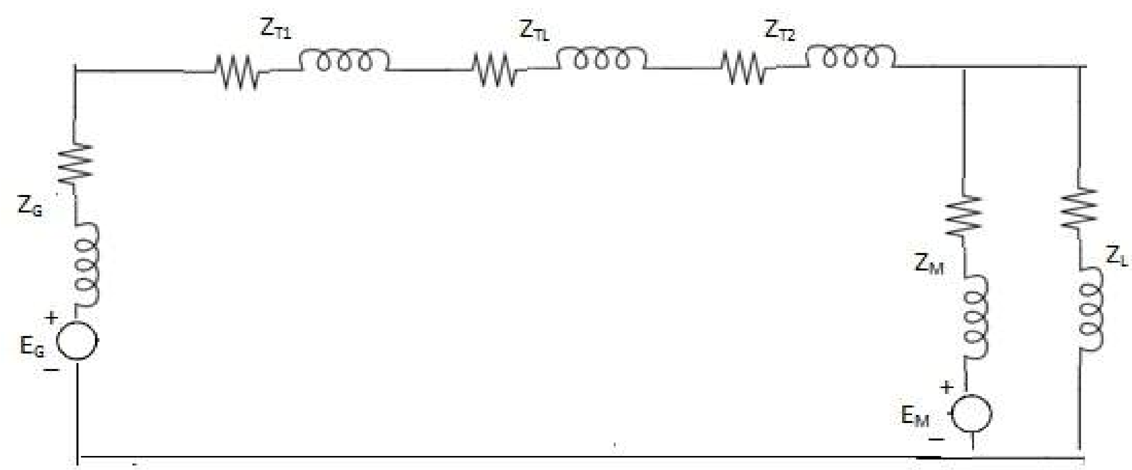
The modern power system is a network of electric components which is used to supply (generating station), transmit (transmission system) and distribute (distribution system) the electrical power.

**27. Name the diagonal and off diagonal elements of bus impedance matrix. (Nov2013)**

The diagonal elements are called as driving point impedances and off diagonal elements are called as transfer impedances.

**28. Draw the impedance diagram for the given single line representation of the power system (May 2014).**




**29.What are the main divisions of Power System?(Nov 2014)**

The main divisions of power systems are :i) Generation ii) Transmission and iii) Distribution.

**30. What is meant by base quantities in per unit representation? (April 2019)**

In the power systems analysis field of electrical engineering, a per-unit system is the expression of system quantities as fractions of a defined base unit quantity. Calculations are simplified because quantities expressed as per-unit do not change when they are referred from one side of a transformer to the other.

**31. Define bus incidence matrix. (Nov/Dec 2019) (Nov/Dec 2020)**

In singular transformation method to find the Ybus the matrix is derived

In general Ybus = [A] [$Y_{primitive}$] $[A]^T$

Where A is defined as the bus incidence matrix.

**32. Give the representation of an off nominal transformer in power system. (Nov/Dec 2020)**

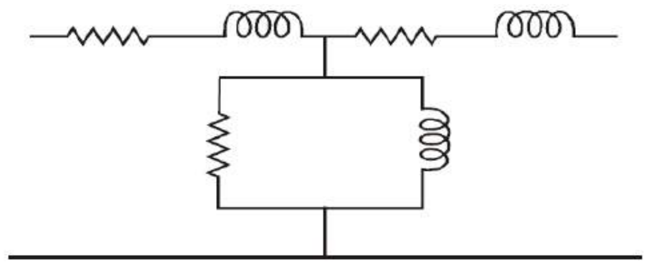
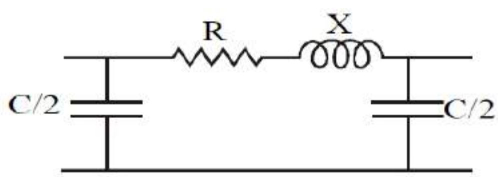
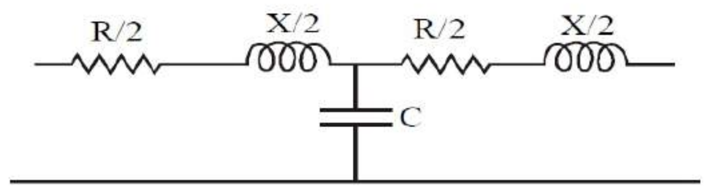


*Figure 1.3 (b) Transformer*




(i) π-Representation




(ii) T-Representation

**PART – B**

**1.** Explain modern power system in detail and draw basic components of power system. **(Nov 2014)**

**2.** Write short notes on the following: i) per-phase analysis of a generator ii) per-phase analysis of 3-winding transformer

**3.** With the help of single line diagram, explain the basic components of a power system. **(May 2011)**

**4.** i)Write detailed notes about the per phase model of a three phase transformer. **(May 2011)**

ii) Draw an impedance diagram for the electric power system shown in figure, showing all the impedances in per unit on a 100 MVA base .Choose 20 KV as the voltage base for generator. The 3ϕpower and line rating are given below.

G1:90MVA,20KV,X=9%.; $T_{r1}$:80MVA,20/220KV,X=16%

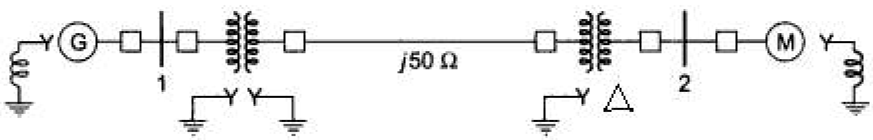
$T_{r2}$: 80MVA, 200/20KV,X=20%; G2:90MVA,18KV,X=9%; Line:200KV,X=120Ω, Load:200KV, S=48MW+j64MVAR.


**5.** i. What are the advantages of per unit computations. **(May 2012)**

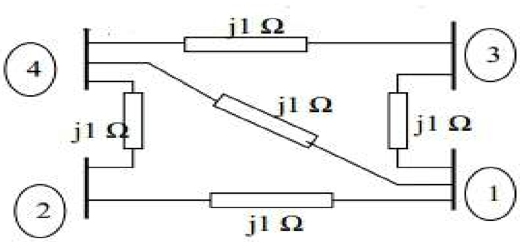
ii. Draw the reactance diagram for the power system shown in figure. Neglect resistance and use a base of 100 MVA, 220 KV in 50Ω line. The ratings of the generator, motor and transformer are given as Generator: 40 MVA, 25 KV, X" =20%; Synchronous motor: 50 MVA, 11KV, X"=30%

Y- Y Transformer: 40 MVA, 33/220KV, X=15% ;

Y - Δ Transformer: 30MVA, 11/220KV, (Δ/Y), X=15%




**6.** Find the bus impedance matrix for the 4 – bus system shown in figure. Consider bus – 4 as the reference bus. **(May 2012)**




**7.** (i) The one-line diagram of a power system is shown in figure. The three-phase power and line ratings are given below. **(Nov 2012, April 2019)**

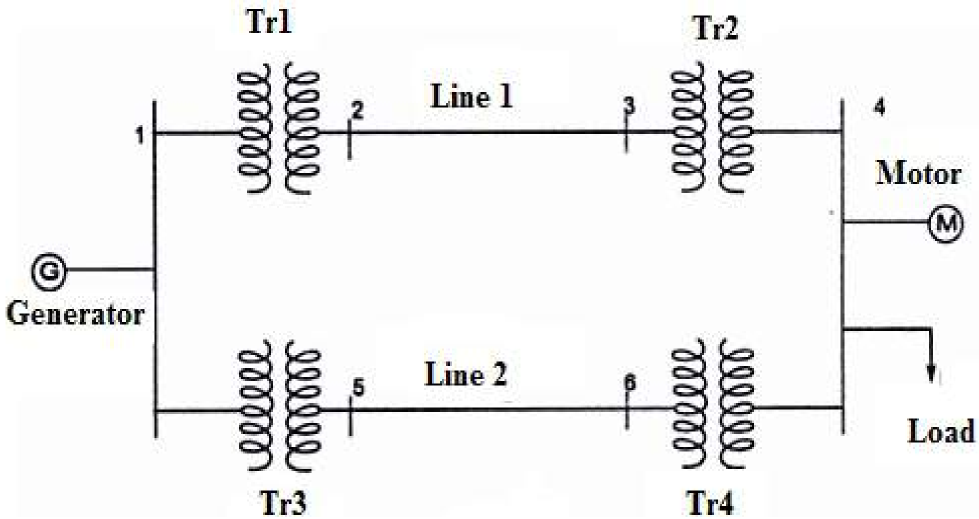
G: 80 MVA 22KV X=9% $T_{r1}$: 50 MVA 22/220 KV X=10%

$T_{r1}$: 40 MVA 220/22 KV X=6.0% $T_{r3}$, $T_{r4}$: 40 MVA 22/110 KV X=6.4%

Line 1: 200 KV X=121Ω Line 2: 110 KV X= 42.35Ω

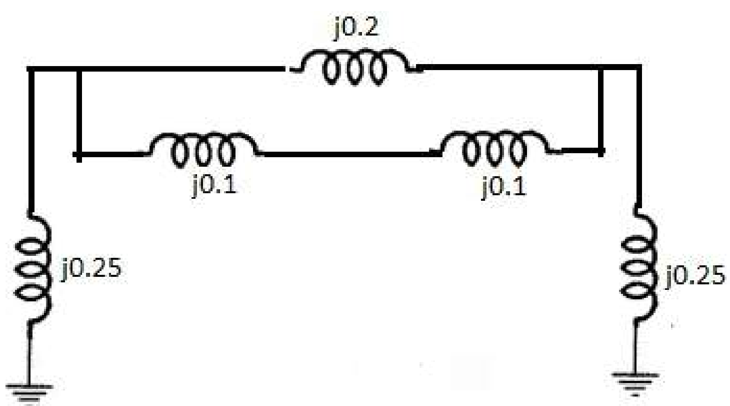
M: 68.85 MVA 20 KV X=22.5% Load: 10 MVAR, 4KV Δ-Connected Capacitor.

Draw an impedance diagram showing all impedance in per –unit on a 100 MVA base. Choose 22KV as the voltage base for generator.

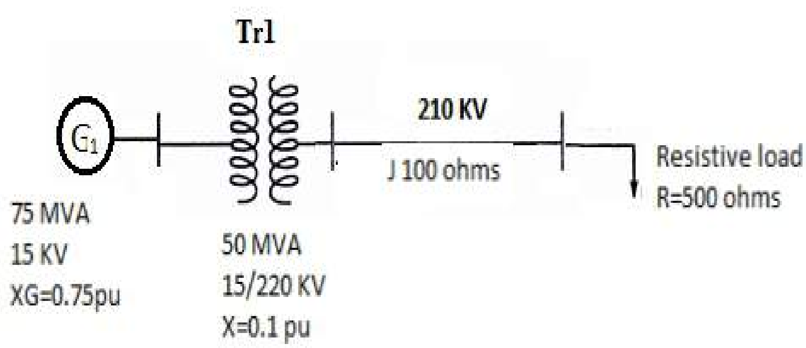



(ii) State the applications of bus admittance matrix (3 Marks)

**8.** Form the bus impedance matrix for the network shown by building algorithms. **(Nov2012, May 2013)**

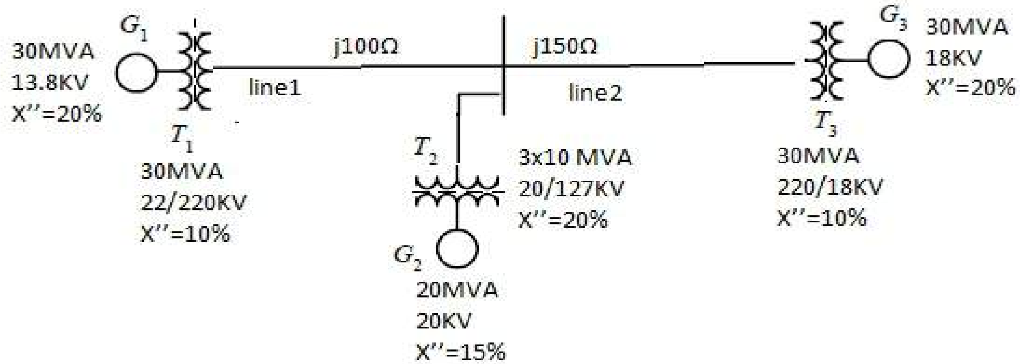



**9.** For the system shown in figure obtain the impedance diagram. Take a base of 100 MVA and 210 KV in the transmission line. **(May 2013)**




10. Why is per unit system used in power system analysis? And list its advantages. **(May 2013)**

11. The Single line diagram of a power system is shown in figure along with components data .Determine the new per unit values and draw the reactance diagram. Assume 25 MVA and 20 KV as new base on generator $G_1$. **(May, 2014)**




12. Describe the $Z_{Bus}$ building algorithms in detailed by using a three bus system. **(May 2014, Nov 2017)**

13. (i) Describe about the representation of loads. **(Nov 2014)**

(ii) Draw the per unit equivalent circuit of single- phase transformer?

14. Obtain the per unit Impedance diagram of the Power system of fig shown below: **(Nov 2014& May 2016)**

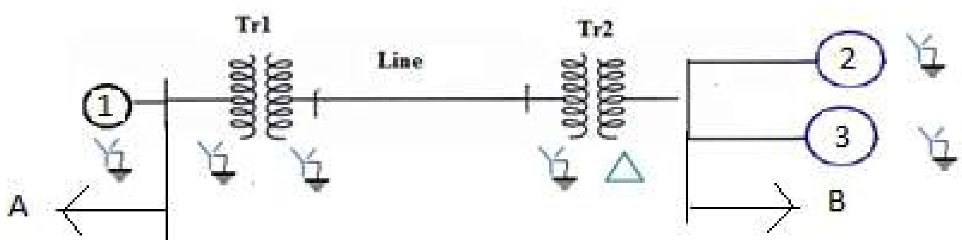



Fig one line diagram representation of a simple power system.

Generator No:- 1: 30 MVA, 10.5 kv, X''= 1.6 ohms

Generator No:- 2: 15 MVA, 6.6 kv, X''= 1.2 ohms

Generator No:- 3: 25 MVA, 6.6 kv, X''= 0.56 ohms

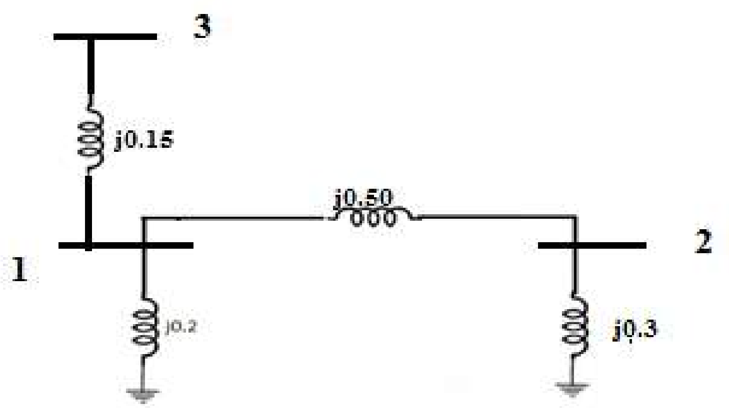
Transformer T1 (3 phase):- 15 MVA, 33/11 KV, X= 15.2 ohms per phase on high tension side .

Transformer T2 (3 phase):- 15 MVA, 33/6.2 KV, X= 16 ohms per phase on high tension side

Transmission line : 20.5 ohms per phase

Load A, 15MW,11KV,0.9 lagging power factor. Load B, 40MW,6.6KV,0.85 lagging power factor.

15. Using the method of building algorithm find the bus impedance matrix for the network shown in figure. **(May 2015).**




16. Draw the reactance diagram for the power system shown in figure. Neglect resistance and use a base of 50MVA and 13.8KV on generator G1.**(Nov 2015, Nov 2017, Nov 2020)**

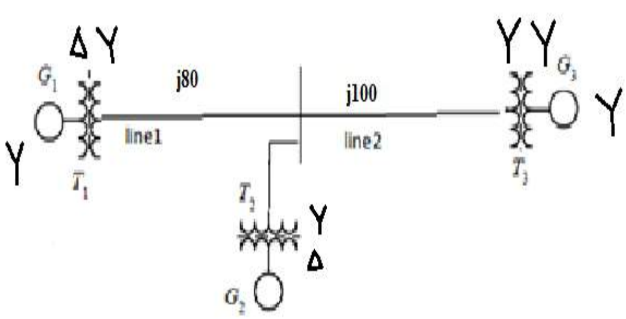
G1: 20 MVA, 13.8 kv, X''= 20% ;G2: 30 MVA, 18.0 kv, X''= 20%;

G3:30 MVA, 20kv, X''= 20%

Transformer T1:- 25 MVA , 220/13.8Kv , X= 10%

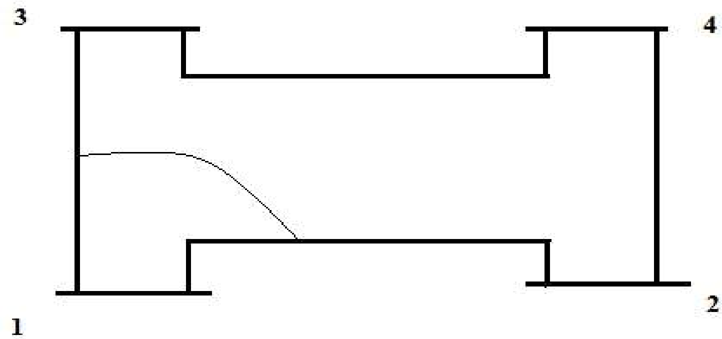
Transformer T2:- 3 single phase unit each rated 10MVA , 127/18Kv , X= 10%

Transformer T3:- 35 MVA , 220/22 Kv , X= 10%




Determine the new values of per unit reactance of G1, T1, Transmission line 1, Transmission line 2, G2, G3, T2 and T3.

17. Form $Y_{bus}$ of the test system shown in figure using singular transformation method. The impedance data is given in table. Take (1) as reference node. **(Nov 2015, Nov 2020)**




| Element No. | Self | | Mutual | |
|---|---|---|---|---|
| | Bus code | Impedance | Bus Code | Impedance |
| 1 | 1-2 | 0.5 | 1-2 | 0.1 |
| 2 | 1-3 | 0.6 | | |
| 3 | 3-4 | 0.4 | | |
| 4 | 2-4 | 0.3 | | |

18. (i) Determine the Y-Bus Matrix by inspection method for line specification as mentioned below. **(May 2016)**

| Line p-q | Impedance in p.u | Half Line charging admittance in p.u |
|---|---|---|
| 1-2 | 0.04+j0.02 | j0.05 |
| 1-4 | 0.05+j0.03 | j0.07 |
| 1-3 | 0.025+j0.06 | j0.08 |
| 2-4 | 0.08+j0.015 | j0.05 |
| 3-4 | 0.035+j0.045 | j0.02 |

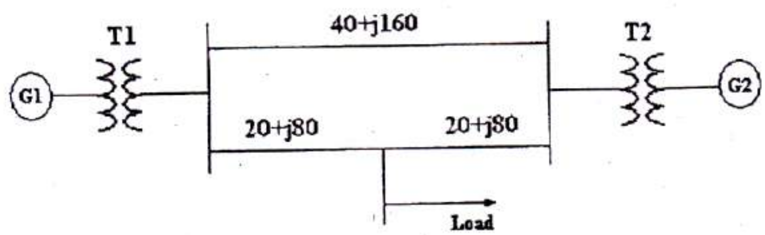
(ii) Draw the π-Model representation of a transformer with off nominal tap ratio 'α'. **(Nov/Dec 2020)**

19. Prepare a per phase schematic of the system shown in fig. and show all the impedance in per unit on a 100 MVA, 132KV base in the transmission line circuit. The necessary data are given as follows:

G1 : 50 MVA, 12.2KV, X=0.15p.u; G2 : 20 MVA, 13.8KV, X=0.15p.u

T1 : 80 MVA, 12.2/161 KV, X=0.1 p.u T2 : 40 MVA, 13.8/161 KV, X=0.1p.u

Load: 50 MVA, 0.8pf lag operating at 154KV. Determine the p.u impedance of the load. **(Nov 2016)**

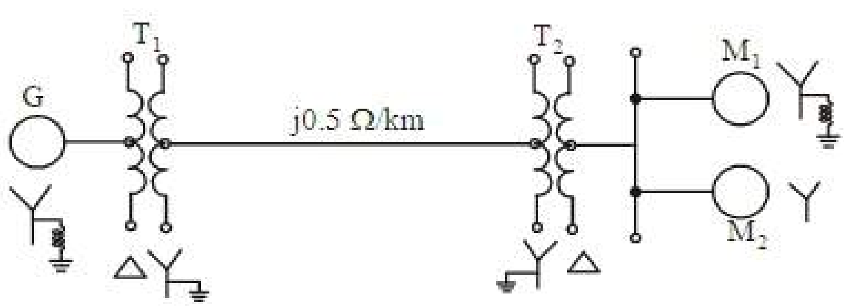



20. The parameters of a 4-bus system are as under:

| Line starting bus | Line ending bus | Line impedance | Line Charging admittance |
|---|---|---|---|
| 1 | 2 | 0.2+j0.8 | j0.02 |
| 2 | 3 | 0.3+j0.9 | j0.03 |
| 2 | 4 | 0.25+j1.0 | j0.04 |
| 3 | 4 | 0.2+j0.8 | j0.02 |
| 1 | 3 | 0.1+j0.4 | j0.01 |

Draw the network and bus admittance matrix **(Nov 2016)**

21. 300 MVA, 20 kV, 3$\phi$ generator has sub transient reactance of 20%. The generator supplies two synchronous motors through a 64 km transmission line having transformers at both ends as shown in Fig. In this, T1 is a 3$\phi$ transformer 350 MVA, 20/230 kV, 10% reactance & Transformer T2 is made of 3 single phase transformer of rating 100 MVA, 127/13.2 kV, 10% reactance. Series reactance of the transmission line is 0.5/km. The ratings of 2 motors are : M1 = 200 MVA, 13.2 kV, 20% & M2 = 100 MVA, 13.2 kV, 20%.Draw the reactance diagram with all the reactance's marked in p.u. **(May 2017, Nov 2018)**



22. Form bus admittance matrix for the data given below using Singular transformation method. Take node '6' as reference node. **(May 2017)**

| Elements | Bus code | X(p.u) |
|---|---|---|
| 1 | 1-2 | 0.04 |
| 2 | 1-6 | 0.06 |
| 3 | 2-4 | 0.03 |
| 4 | 2-3 | 0.02 |
| 5 | 3-4 | 0.08 |
| 6 | 4-5 | 0.06 |
| 7 | 5-6 | 0.05 |

23. Draw the impedance diagram of the power shown in below figure 2. (**Nov 2018)**

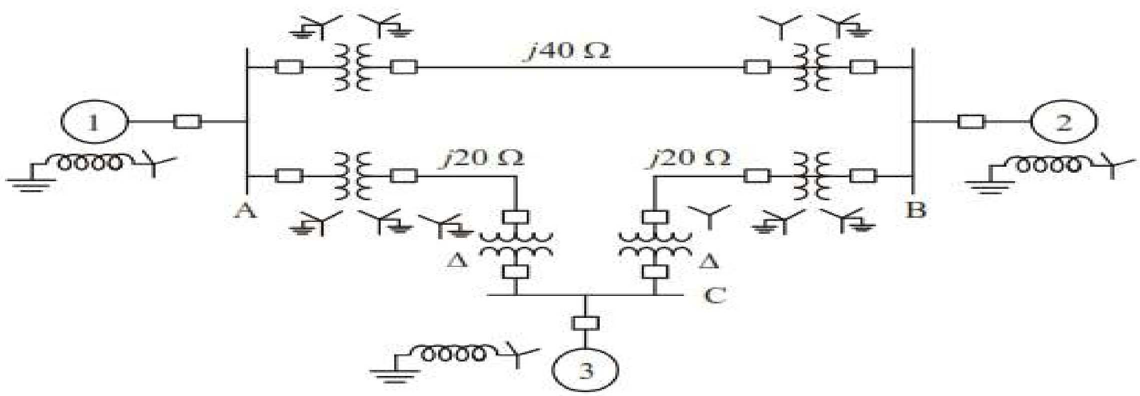



***Figure 2***

Mark impedance in power unit. Neglect resistance and use a base of 50 MVA, 138 KV in the 40 line. The ratings of the generator, motors and transformers are;

Generator 1: 20 MVA, 18 kV, X = 20%

Generator 2: 20 MVA, 18 kV, X = 20%

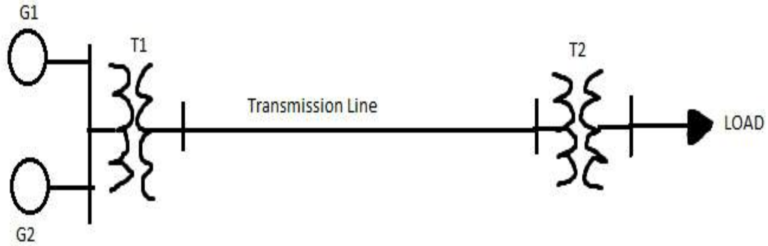
Synchronous motor 3:30 MVA, 13.8 kV, X" = 20%

Three phase Y-Y transformers: 20 MVA, 138Y/20Y kV X = 10%

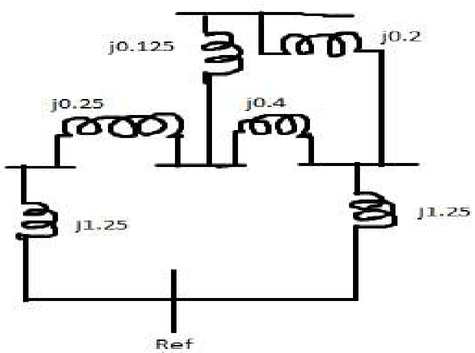
Three phase Y- Δ transformers: 15 MVA, 138Y/13.8 Δ kV, X = 10%.

24. In a single line diagram, shown in figure, each three phase generator G is rated at 200MVA, 13.8 KV and has a reactance of 0.85pu and are generating 1.15pu. Transformer T1 is rated at 500MVA, 13.5KV/220KV and has a reactance of 8%. The transmission line has a reactance of 7.8ohm. Transformer T2 has a rating of 400MVA, 220KV/33KV and a reactance of 11%. The load is 250MVA at a PF of 0.85 lag. Convert all quantities

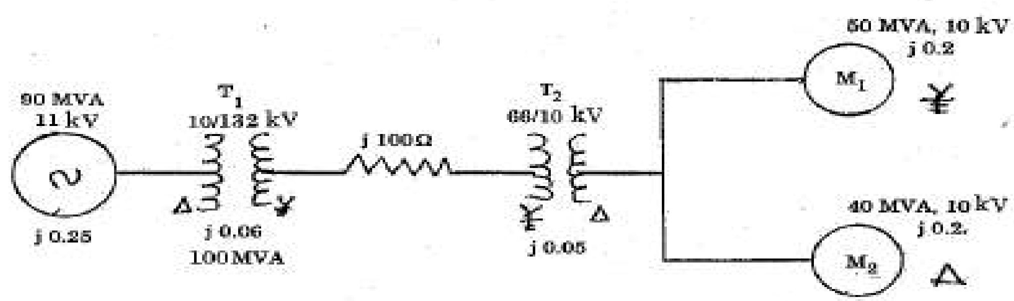
to a common base of 500MVA and 220KV on the line and draw the circuit diagram with values expressed in pu.



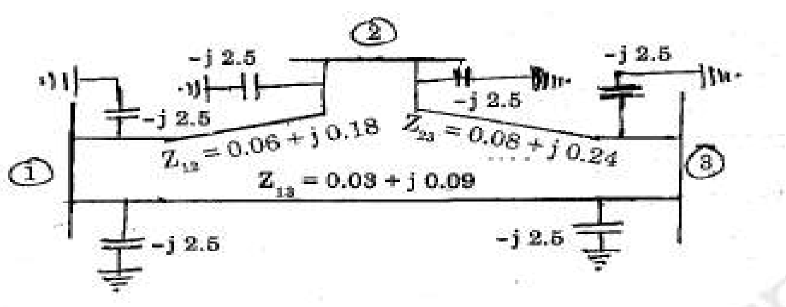

25. Determine Z bus for the system whose reactance diagram is shown in fig. where the impedances is give in pu. Preserve all the nodes.



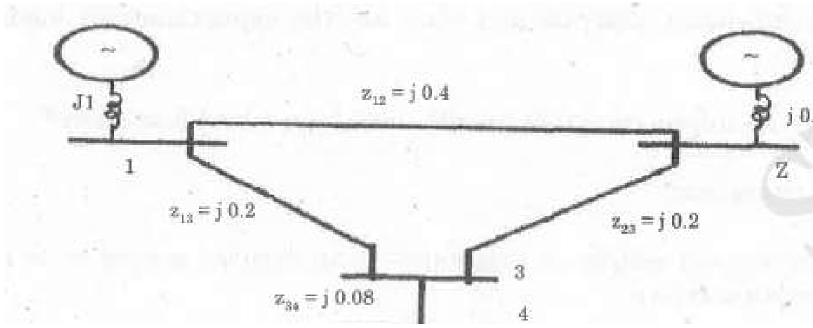

26. Calculate the per unit quantities of the given one-line diagram. $T_2$ is composed of three single phase units each rated at 30MVA, 66/10kV with 5% reactance. Take generator rating as base. **(Nov/Dec 2019)**




27. Determine the bus admittance matrix for the given power system.( **Nov/Dec 2019).**



28. From the impedance diagram shown in fig, Compute the bus admittance matrix and draw the admittance matrix and draw the admittance diagram. (**April/May 2019)**




29. Fig shows a single-line diagram of a power system. The ratings of generators and transformers are:

Generator $G_1$ : 30MVA, 6.6kV, j0.2pu

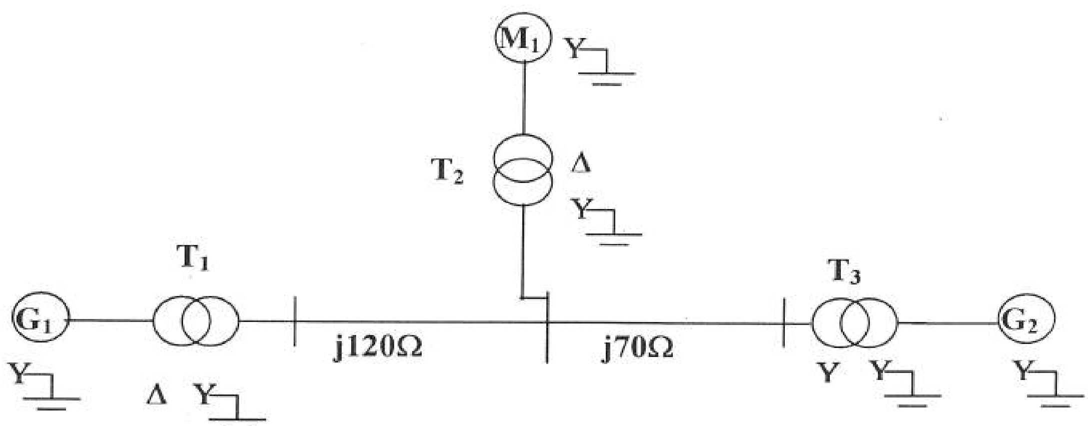
Generator $G_2$ : 15MVA, 6.6kV, j0.15pu

Motor $M_1$ : 15MVA, 6.6, j0.15pu

Transformer $T_1$ : 30MVA, 6.6 Δ - 115Y kV, j0.2pu

Transformer T2 : 15MVA, 6.6 Δ - 115Y kV, j0.1pu

Transformer T3 : 15MVA, 6.6 Δ - 115Y kV, j0.1pu




Draw the impedance diagram with all values in pu on a base of 30 MVA, 6.6kV in the circuit of generator G1 **(Nov/Dec 2020)**

30. (i) Subtransient reractance of a 500MVA, 18 kV generator is 0.25pu on its ratings. It is connected to a network through a 20/400kV transformer. Find out the subtransient reactance of a generator on a base of 100 MVA and 20kV.

(ii) Derive the π-Model for a transformer with off-nominal tap-ratio. **(Nov/Dec 2020)**

# UNIT – II POWER FLOW ANALYSIS

## PART – A

**1. What is power flow study or load flow study? (Nov 2014)**

The study of various methods of solution to power system network is referred to as load flow study. The solution provides the voltages at various buses, power flowing in various lines and line-losses.

**2. What is the need for load flow study? ( May 2016 & Nov 2017, Nov 2020)**

The load flow study of a power system is essential to decide the best operation of existing system and for planning the future expansion of the system. It is also essential for designing a new power system.

**3. What are the different types of buses in a power system?(May 2016 & Nov 2017)**

The buses of a power system can be classified into three types based on the quantities being specified for the buses. The different types of buses are,(i) Load bus or PQ bus (ii)Generator bus or voltage controlled bus or PV bus(iii)Slack bus (or) swing bus (or) reference bus.

**4. When the generator bus is treated as load bus? (Nov 2013, May 2014, Nov 2015, Nov 2018, Nov 2020)**

If the reactive power of a generator bus violates the specified limit, then the generator bus is treated as a load bus. The reactive power of that particular bus is equated to the limit it has violated and the previous iteration value of bus voltage is used for calculating current iteration value.

**5. What are the advantages and disadvantages of G-S method?**

**Advantages:** i) Calculations are simple, so the programming task is less ii) the memory requirement is less iii) Useful for small systems

**Disadvantages:** i) Requires large number of iterations to reach convergence. ii) Not suitable for large systems iii) Convergence time increases with size of the system

**6. What are the advantages and disadvantages of N-R method? (Nov/Dec 2019)**

**Advantages:** i) The N-R method is faster, more reliable and the results are accurate ii) Requires less number of iterations for convergence. iii) The number of iterations is independent of the size of the system.vi) Suitable for large size system.

**Disadvantages:** i) Programming is more complex ii) The memory requirement is more iii) Computational time per iteration is higher due to large number of calculations per iteration.

**7. How the disadvantages of N-R method are overcome?**

The disadvantages of large memory requirement in NR method can be overcome by decoupling the weak coupling between P- δ and Q-V (i.e using de coupled load flow algorithm). The large computational time per iteration can be reduced by simplifying the decoupled load flow equations. The simplifications are made based on the practical operating conditions of a power system.

**8. How are the diagonal elements of $Y_{bus}$ known as?**

The diagonal elements of $Y_{bus}$ are known as the short circuited driving point admittance or self-admittance of the buses.

**9. State the major steps involved in load flow studies?**

The major steps involved in load flow studies are i) Mathematical modeling of the power system; this would be a set of non-linear algebraic equations. ii) Solution of the non-linear equations through an iterative technique.

**10. Why acceleration factor is used in the G-S method? (May 2018)**

The acceleration factor is used in G-S method to increase the rate of convergence of the iterative process. The value of acceleration factor varies from 1.2 to 1.6.

**11. What is the need of load flow solution?**

The load flow solution is essential for designing a new power system and for planning extension as well as operation of the existing one for increased power demand.

**12. What is load bus?**

A load bus is one at which the active power and reactive power are specified. In this bus, its voltage can be allowed to vary within permissible values. i.e ±5%. Also bus voltages phase angle is not very important for the load.

**13. How the convergence of N-R method is speeded up?**

The convergence of N-R method is speeded up using fast decoupled load flow (FDLF) method. In FDLF, the weak coupling between P-V and Q- δ are decoupled and the equations are further simplified equations are further simplified using the practical operating conditions of the power system.

**14. What are the advantages of decoupled method over N-R method?**

i) This method is simple and computationally efficient than the N-R method.

ii) It requires less memory compared to N-R method.

**15. What is the need for voltage control in a power system?**

The various components of a power system (or equipments connected to power system) are designed to work satisfactorily at rated voltages. If the equipments are not operated at rated voltages then the performance of the equipments will be poor and the life of the equipments will reduce. Hence the voltages at various points in a power system should be maintained at rated value (specified value)

**16. How the reactive power of a generator is controlled?**

The reactive power of a generator is controlled by varying the magnitude and phase of induced emf, which in turn varied by varying excitation. For an increase in reactive power the magnitude of induced emf is increased and its phase angle is decreased. For a reduction in reactive power the magnitude of induced emf is decreased and its phase angle is increased.

**17. What is Slack or swing bus? (May 2011, Nov/Dec 2019, April 2019).**

A bus is called swing bus when the magnitude and phase of bus voltage are specified for it. The swing bus is the reference bus for load flow solution and it is required for accounting line losses. Usually one of the generator bus is selected as the swing bus.

**18. What is Jacobian matrix? How the elements of Jacobian matrix are ermined?(May 2011, Nov 2016)**

The matrix formed the first order derivatives of load flow equations is called Jacobian matrix (J).The elements of Jacobian matrix will change in every iteration. In each iteration the elements of this matrix are obtained by partial differentiating the load flow equations with respect to an unknown variable and then calculating the first derivatives using the solution of previous iteration.

**19. What are the information that are obtained from a power flow study? (May2012, April 2019)**

Power flow or load flow study is used to find the state variables of the power system. the state variables of the power systems are voltage magnitude and angle. By using this value the power flows in various lines and the losses are calculated.

**20. Compare Gauss-Seidal and Newton Raphson methods of load flow solutions. (May 2012, Nov 2015 & May 2017)**

| S. N | Gauss Seidal | Newton Raphson |
|---|---|---|
| 1. | Reliable | More reliable |
| 2. | Require large number of iterations to reach convergence. It has linear convergence characteristics | Faster. Require less number if iteration to reach convergence It has quadratic convergence characteristics. |
| 3. | Programming task is less | Programming is more complex. |
| 4. | Suitable for small size system and not suitable for large system. Number iterations increases with increase in size. | Suitable for large size system. Number of iterations does not depend on size of the system. |
| 5. | Memory required is less | Memory required is more. |

**21. Why power flow analysis is made? (Nov2012)**

Power flow analysis is performed to calculate the magnitude and phase angle of voltage at the buses and also the active power and reactive volt amperes flow for the given terminal or bus conditions. The variables associated with each bus or node arei) magnitude of voltage (v) ii) phase angle of voltage (δ) iii) active power (P) iv) reactive volt amperes (Q).

**22. What is acceleration factor? (Nov2012, May 2013)**

The acceleration factor is a numerical multiplier which is used to increase the rate of convergence in an iterative process. The previous value at the bus is multiplied by the acceleration factor to obtain a correction to be added to previous values.

**23. What is the need of slack bus? (May 2013, May 2014, Nov 2016, Nov 2018, May 2018) (Nov/Dec 2020)**

The slack bus is needed to account for transmission line losses. In a power system, the total power generated will be equal to sum of power consumed by loads and losses. In a power system only the generated power and load power are specified for buses. The slack bus is assumed to generate the power required for losses. Since the losses are unknown the real and reactive power are not specified for slack bus .They are estimated through the solution of load flow equations.

**24. Why do $Y_{Bus}$ used in load flow study instead of $Z_{Bus}$? (Nov 2013)**

$Y_{bus}$ is sparse matrix ie. zero elements are more. So that the no of equations need to be solved to obtain the power flow solution is less compared to using a Zbus (full matrix). Using Ybus matrix is occupying less memory than using the Zbus matrix.

**25. Define voltage controlled bus (Nov 2014)**

These are the buses where generators are connected. Therefore the power generation in such buses is controlled through a prime mover while the terminal voltage is controlled through the generator excitation. Keeping the input power constant through turbine-governor control and keeping the bus voltage constant using automatic voltage regulator, we can specify constant $P_{Gi}$ and $|V_i|$ for these buses. This is why such buses are also referred to as P-V buses. It is to be noted that the reactive power supplied by the generator $Q_{Gi}$ depends on the system configuration and cannot be specified in advance. Furthermore we have to find the unknown angle $\delta_i$ of the bus voltage.

**26. Why is Bus impedance matrix preferred for fault analysis? (May 2015) (or) The Z- bus method is very suitable for fault studies rather than Y bus. Why? (Nov/Dec 2020)**

Bus impedance matrix is preferred for the fault analysis because fault analysis required full matrix for calculating line flows in all the lines. The admittance matrix is sparse in nature, so it is not preferred for fault analysis.

**27. Write the quantities that are associated with each bus in a system. (May 2017)**

| Bus type | Quantities specified | Quantities to be obtained |
|---|---|---|
| Slack bus | **$\|V\|$, δ** | P,Q |
| Load bus | P,Q | **$\|V\|$, δ** |
| Generator bus | P, **$\|V\|$** | Q, **δ** |

## PART – B

1. State the load flow problem and derive load flow equation. **(May 2014, Nov 2018)**

2. (a) What are the practical application of the power flow analysis?

(b) Derive the mathematical model of phase shifting transformer to be used in a power flow analysis.

3. The following is the system data for a load flow solution: **(Nov 2015)**

| Bus code | Admittance |
|---|---|
| 1-2 | 2.0-j8.0 |
| 1-3 | 1.0-j3.0 |
| 2-3 | 0.6-j2.0 |
| 2-4 | 1.0-j4.0 |
| 3-4 | 2.0-j8.0 |

| Bus code | P | Q | V | Remarks |
|---|---|---|---|---|
| 1 | - | - | 1.05+j0.0 | Slack |
| 2 | 0.5 | 0.2 | 1.0+j0.0 | PQ |
| 3 | 0.4 | 0.3 | 1.0+j0.0 | PQ |
| 4 | 0.3 | 0.1 | 1.0+j0.0 | PQ |

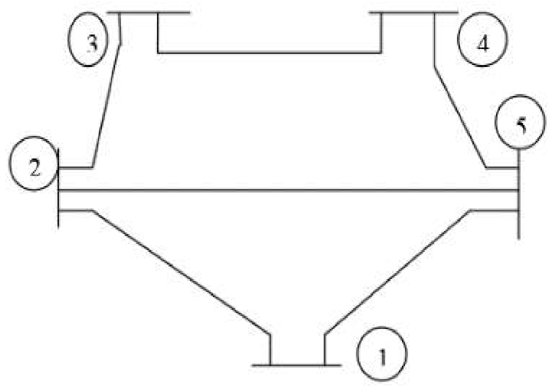
Determine the voltage at the end of first iteration using G-S method. Take acceleration factor= 1.4.

4. With neat flow chart explain the computational procedure for load flow solution using Gauss Seidal load flow solution. **(May 2011, May 2016, Nov 2017 , Nov 2018 & Nov 2019, April 2019)**

5. Figure shows a five bus system. Each line has an impedance of (0.05+ j0.15) pu. The line shunt admittance may be neglected. The bus power and voltage specifications are given in table. **(May 2012)**

| Bus | $P_L$ | $Q_L$ | $P_G$ | $Q_G$ | V | Bus Specification |
|---|---|---|---|---|---|---|
| 1 | 1.0 | 0.5 | - | - | $1.02\angle 0$ | Slack bus |
| 2 | 0 | 0 | 2 | - | 1.02 | PV bus |
| 3 | 0.5 | 0.2 | 0 | 0 | - | PQ Bus |
| 4 | 0.5 | 0.2 | 0 | 0 | - | PQ bus |
| 5 | 0.5 | 0.2 | 0 | 0 | - | PQ bus |

(i)Form $Y_{bus}$ (ii)Find $Q_2$, $\delta_2$, $V_3$, $V_4$, and $V_5$ after first iteration using Gauss seidal method. Assume $Q_{2min}$=0.2pu, $Q_{2max}$= 0.6pu.



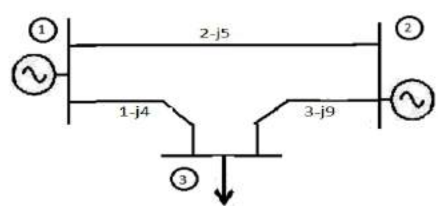

6. What is Jacobian Matrix? How the elements of Jacobian matrix are computed?**(May 2012, Nov 2012, Nov2018)**

7. Draw the flow chart and explain the algorithm of Newton Raphson iterative method when the system contains all types of buses**.(May 2012, Nov 2014, May 2014, May 2016, Nov2016, May 2017, Nov 2017, Nov 2020)**

8. Compare G-S and N-R methods of load flow analysis.**(Nov 2012)**

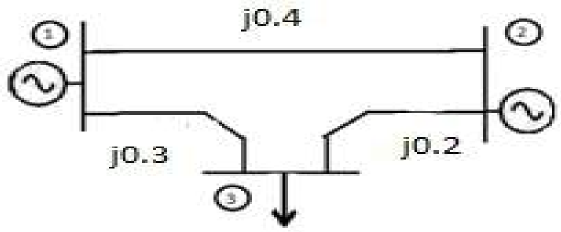
9. The figure given below shows a power system. **(Nov 2012)**

Bus 1: Slack bus ESpecified=1.05∟0º ;Bus 2: PV bus |E|Specified= 1.2 p.u PG= 3 p.u; Bus 3: PQ bus PL= 4 p.u QL=2 p.u .Carry out one iteration of load flow solution by Gauss-Seidal method. Take Q limits of generator 2 as $0 \leq Q < 4$ Take α = 1.

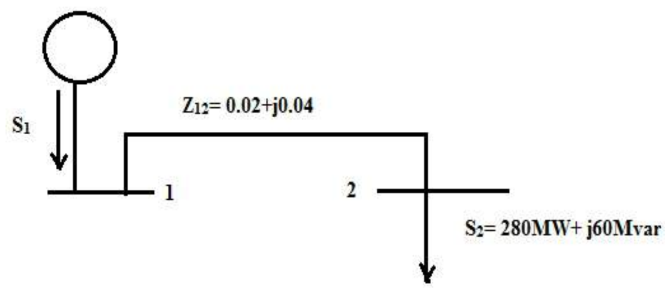



10. Describe the step by step procedure for load flow solution from Gauss seidal method, if PV and PQ buses are present along with slack bus.**(May 2011, May 2013, May 2014, Nov 2015)**

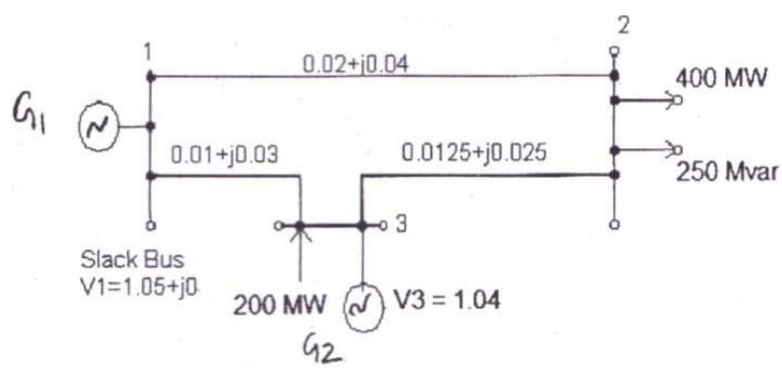
11. Fig. shown below a three bus power system Bus 1: Slack bus VSpecified=1.05∟0º ;Bus 2: PV bus |V|Specified= 1.02 p.u ,PG= 0.3 p.u; Bus 3: PQ bus $P_L$= 0.4 p.u $Q_L$=0.2 p.u .Carry out one iteration of load flow solutions by Gauss Seidel method. Neglect limits on reactive power generation? **(Nov 2014, May 2018)**




12. In the power system network shown in figure, bus 1 is slack bus with $V_1$= 1.0+j 0.0 pu and bus 2 is a load bus with $S_2$= 280MW+j60 MVAr. The line impedance on a base of 100 MVA is Z= 0.02+j0.04 pu. Using Gauss Seidal method, determine $V_2$. Use an initial estimate of $V_2^{(0)}$ = 1.0+j0.0 and perform four iterations. Also find S1 and the real, reactive power loss in the line, assuming that the bus voltages have converged. **(May 2015)**

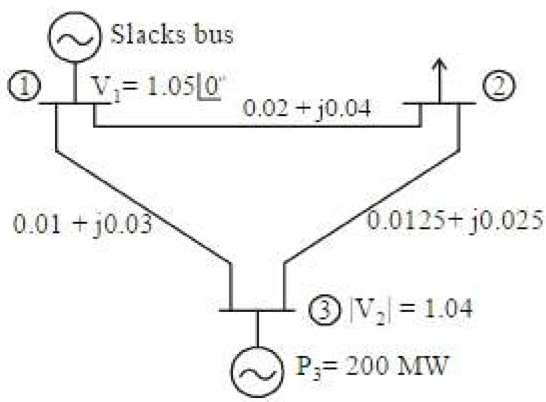



13. The fig shows the one line diagram of a simple 3 bus power system with generators at buses 1 and 3. Line impedances are marked in p.u on a 100MVA base. Determine the bus voltages at the end of second iteration using Gauss – Seidal method. **(Nov 2016, April 2019, Nov 2020).**




14. Single line diagram of a simple power system, with generators at buses 1and 3 is shown in Fig. The magnitude of voltage at bus 1 is 1.05p.u. Voltage magnitude at bus 3 is fixed at 1.04 p.u with active power generation of 200 MW. A load consisting of

400 MW and 250 MVAR is taken from bus 2. Line impedances are marked in p.u on a 100 MVA base and the line charging susceptances are neglected. Determine the voltage at buses 2 and 3 using Gauss-Seidal method at the end of first iteration. Also calculate Slack bus power **(May 2017, Nov 2020)**




15. Perform an iteration of Newton-Raphson load flow method and determine the power flow solution for the given system. Take base MVA as 100.

| | BUS | | R(p.u) | X(p.u) | Half line charging admittance ($Y_p$/2)p.u |
|---|---|---|---|---|---|
| LINE | FROM | TO | | | |
| 1 | 1 | 2 | 0.0839 | 0.5183 | 0.0636 |

| BUS | $P_L$ | $Q_L$ |
|---|---|---|
| 1 | 90 | 20 |
| 2 | 30 | 10 |

16. The one-line diagram of a simple three bus power system with generators at bus 1 and 2. The magnitude of voltage at bus 1 and 2 are adjusted to 1.06 and 1.05p.u. The scheduled load at bus 2 is marked. Line impedance are marked to per unit on a 100MVA base and the line charging is neglected. Solve by N-R method. **Nov/Dec 2019.**

| Bus Number | Type | Generator (p.u.) | | Load (p.u.) | | Voltage (p.u.) | Angle (deg) | Reactive Power Limit | |
|---|---|---|---|---|---|---|---|---|---|
| | | $P_g$ | $Q_g$ | $P_d$ | $Q_d$ | | | $Q_{min}$ | $Q_{max}$ |
| 1 | Slack | 0 | 0 | 0 | 0 | 1.06 | 0 | – | – |
| 2 | PQ | 0 | 0 | 6 | 2.5 | 0 | 0 | – | – |
| 3 | PV | 2 | 0 | 0 | 0 | 1.05 | 0 | 0.1 | 2.5 |

| Element | Bus Code | Self-impedance (Ω) |
|---|---|---|
| 1 | 1-2 | 0.01 + j0.05 |
| 2 | 1-3 | 0.07 + j0.2 |
| 3 | 2-3 | 0.02 + j0.15 |

17. A sample system is described in fig. The line data, bus data and load flow results are given Table 1 and 2. Compute the following:

I) Slack bus power.

II) Reactive power Generation from G2.

III) Line Flows.

IV) Line Losses. **(Nov/Dec 2020)**

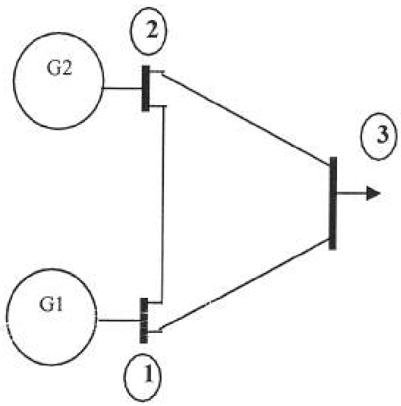



Fig. 3

Table 1 Line Data

| Line | Admittance | Half line charging admittance |
|---|---|---|
| 1-2 | 1.47 – j5.88 | j0.15 |
| 1-3 | 2.94 – j11.77 | j0.07 |
| 2-3 | 2.75 – j9.17 | j0.04 |

Table 2 Bus Data and Load Data

| Bus | Bus voltage | Generation | | Load | |
|---|---|---|---|---|---|
| | | MW | MVAR | MW | MVAR |
| 1 | $1.04\angle 0°$ | -- | -- | 0 | 0 |
| 2 | $1.02\angle -3.09°$ | 100 | - | 50 | 20 |
| 3 | $0.93\angle -7.01°$ | 0 | 0 | 250 | 150 |

## UNIT – III FAULT ANALYSIS - BALANCED FAULT

## PART – A

**1. What is Short Circuit MVA and how it is calculated? (May 2015, Nov 2016)**

The short circuit capacity or the short circuit MVA at a bus is defined as the product of the magnitudes of the rated bus voltage and the fault current. S.C MVA capacity of the circuit breaker = √ 3 x pre fault voltage in KV x S.C current in KA.

**2. How the shunt and series fault are classified? (Nov, 2016)**

SERIES FAULT: (a) One open conductor fault (b) Two open conductor fault

SHUNT FAULT: (a) Symmetrical or balanced fault (i) Three phase Fault (LLLG)

(b) Unsymmetrical or unbalanced fault ( i) Line to line fault (LL) (ii) Line to ground fault (LG) (iii) Double line to ground fault. (LLG).

**3. What are the factors to be considered for selecting the C.B.?**

The factors to be considered in selecting a circuit breaker for a protection scheme are: Normal operating voltage, Momentary, interrupting current. Speed of the breaker and S.C interrupting MVA.

**4. What you mean by symmetrical faults? (Nov 2014, May 2016, Nov 2017, May 2018, Nov/Dec 2019).**

The fault is called symmetrical fault if the fault current is equal in all the phases and the phase difference between any two phases is equal.

**5. What you mean by doubling effect?**

The first peak of the resultant current will become twice the peak value of the final steady current. This effect is called as doubling effect.

**6. What you mean by transient and sub transient reactance? (May 2018)**

$X_d'$(transient reactance) is the ratio of no load emf and the transient symmetrical r.m.s current.

$X_d''$(sub transient reactance) is the ratio of no load emf and the sub transient symmetrical r.m.s current.

**7. What is the application of transient reactance?**

The transient and sub transient reactance helps in calculating the interrupting and maximum momentary s.c currents.

**8. Give the various assumptions made for fault analysis. (May 2018, April 2019)**

The assumptions made in analysis of faults are: i) Each synchronous machine model is represented by an e.m.f behind a series reactance ii) In the transformer models the shunt that account for core loss and magnetizing components are neglected.iii) In the transmission line models the shunt capacitances are neglected. iv)All series resistances in generators, transformers, lines are neglected. v) In the normal operating conditions the pre fault voltage may be considered as 1.0 p.u.vi) Load impedances are neglected; hence the pre fault system may be treated as unloaded. vii) As the pre fault currents are much smaller than the post fault currents the pre fault currents can be neglected.

**9. Name any methods of reducing short circuit current.**

By providing neutral reactance and by introducing a large value of shunt reactance between buses.

**10. What is the reactance used in the analysis of symmetrical faults on the synchronous machines as its equivalent reactance.**

i) Sub transient reactance $X_d''$ ii) Transient Reactance $X_d'$ iii) Synchronous reactance $X_d$

**11. What is synchronous reactance?**

It is the ratio of induced emf and the steady state r.m.s current. $X_d = E_g / I$

It is the sum of leakage reactance and the armature reaction reactance. It is given by $X_d = X_l + Xa$,

Where, $X_d$ = Synchronous reactance. $X_l$= Leakage reactance & $X_a$ = Armature reaction reactance.

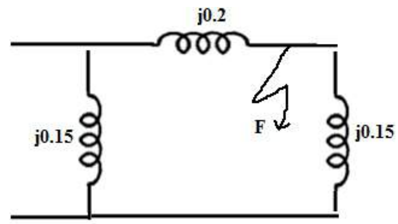
**12. What are the causes of fault in power system. (May 2015)**

A fault may occur on a power system due to a number of reasons. Some of the causes are (i)Insulation failure of the system, (ii) Falling of a tree along a line, (iii) Wind and ice loading on the transmission lines, (iv)Vehicles colliding with supporting structures, (v) Overloading of underground cables, (vi)Birds shorting the lines.

**13. Name the main differences in representation of power system for load flow and short circuits studies**

| S.N | Load flow studies | Short circuit studies |
|---|---|---|
| 1 | The resistances and reactances are considered | The resistances are neglected |
| 2 | To solve load flow analysis, the bus admittance matrix is used | To solve load flow analysis, the bus impedance matrix is used |
| 3 | It is used to determine the exact voltages and currents | Prefault voltages are assumed to be 1 p.u and the prefault current can be neglected |

**14. Find the fault current in figure, if the pre fault voltage at the fault point is 0.97p.u?**




$$Z_{th} = j\frac{(0.15 + 0.2)X0.15}{(0.15 + 0.2) + 0.15} = j0.105 \text{ pu}$$

Fault Current

**15. What is the reason for transients during short circuits?**

The fault or short circuits are associated with sudden change in currents. Most of the components of the power system have inductive property which opposes any sudden change in currents and so the faults (short circuit) are associated with transients.

**16. What is the significance of transient reactance in short circuit studies? (May 2017)**

The transient reactance is used to estimate the transient value of fault current. Most of the circuit breakers open their contacts only during this period. Therefore, for a circuit breaker used for fault clearing, its interrupting short – circuit rating should be less than the transient fault current.

**17. What is the significance of sub - transient reactance in short circuit studies? (May 2017, Nov 2018, Nov 2020)**

The sub - transient reactance is used to estimate the initial value of fault current immediately on the occurrence of the fault. The maximum momentary short circuit current rating of the circuit breaker used for protection or fault clearing should be less than this fault clearing value.

**18. How to conduct fault analysis of a power system network?**

The fault current and voltages in the various part of the system can be determined by any one of the following methods: By using KVL & KCL method, using equivalent circuit representation and by using bus impedance matrix

**19. What is meant by fault calculations? (May 2018)**

The fault condition of a power system can be dived into sub transient, transient and steady state periods. The currents in the various parts of the system and in the fault are different in these periods. The estimation of these currents for various types of faults at various locations in the system are commonly referred as fault calculations.

**20. Mention the objectives of short circuit studies or fault analysis. (May 2011, Nov 2012, Nov2014, Nov 2016, Nov 2018) (or) What is the need of short circuit analysis? (Nov/Dec 2019).**

The short circuit studies are essential in order to design or develop the protective schemes for various parts of the system. The protective scheme consists of current and voltage sensing devices, protective relays and circuit breakers. The selection or proper choice of these mainly depends on various currents that may flow in the fault conditions.

**21. Write down the balanced and unbalanced faults occurring in a power system. (May 2011)**

BALANCED FAULT:3 phase short circuit fault

UNBALANCED FAULT: Single line to ground fault, line to line fault and double- line to ground fault.

**22. Distinguish symmetrical and unsymmetrical fault. (Nov 2012, May 2013)**

The fault is called Symmetrical fault if the fault current is equal in all the phases.eg. 3ϕ short circuit fault. The fault is called unsymmetrical fault if the fault current is not equal in all the three phases. eg. i) single line to ground fault ii) line to line fault iii) double line to ground fault iv) open conductor fault

**23. What is meant by fault level? (May 2013, April 2019) (Nov/Dec 2020)**

It relates to the amount of current that can be expected to flow out of a bus in to a 3 phase fault. Fault level in MVA at bus

$i = V_{i\,pu\,nominal} \; * \; I_{i\,pu\,fault} \; * \; S_{3\phi\,base}$.

**24. Give the frequency of various faults occurrence in ascending order (Nov 2013, May 2014 & May 2017)**

| **Types of Faults** | **Relative Frequency of Occurrence of Faults** |
|---|---|
| 3 phase fault | 5% |
| Double Line to Ground Fault | 10% |
| Line to Line Fault | 15% |
| Single Line to Ground Fault | 70% |

**25. Define bolted fault. (May 2014, May 2016 & Nov 2017, Nov 2020)**

A fault represents a structural network change equivalent with that caused by the addition of impedance at the place of the fault. If the fault impedance is zero, then the fault is referred as **bolted** or **solid fault**.

**26. For a system, the bus impedance matrix was found to be Z=** $j\begin{bmatrix} 0.0450 & 0.0075 & 0.030 \\ 0.0075 & 0.06375 & 0.030 \\ 0.030 & 0.030 & 0.0210 \end{bmatrix}$**.**

**The impedances are in pu. A three phase symmetrical fault occurs at bus 3 through a fault impedance of $Z_f$ = j0.19 pu. Find out the post fault voltage at bus 2 assuming zero prefault current.(May 2015).**

**Solution:** $I_k(F) = \dfrac{V_k(0)}{Z_{kk} + Z_f}$

$$I_3(F) = \frac{V_k(0)}{Z_{33} + Z_f} = \frac{1\angle 0^\circ}{j0.0210 + j0.19} = -j4.7393$$

The post fault voltage, $V_2(0) - Z_{23} I_3(f) = 1\angle 0^\circ - (j0.06375)(-j4.7393) = 1 - 0.302 = 0.698\,pu$

**27. What is direct axis reactance? (Dec 2015)**

The direct axis is defined as the direction along the rotor that the field winding current causes magnetic flux to flow. $X_d$ - direct axis reactance.

**28. For a fault at a given location, rank the various faults in the order of severity. (Nov 2020)**

The rank of the faults based on the severity is listed below,

- Three phase symmetrical fault
- Double line to ground fault
- Line to line fault
- Single line to ground fault

**PART – B (C301.3)**

1. Two synchronous motors are connected to the bus of a large system through a short transmission line as shown. The ratings of the various components are: Motor each: 1MVA, 440V, 0.1p.u reactance. Line: 0.05Ω reactance. Large system S.C MVA at 440V bus is 8.0. When two motors are in operation at 440V, calculate the S.C current (symmetrical) fed into a 3 phase fault at the motors.

2. A small generating station has a bus bar divided into three sections. Each section is connected to a tie- bar with reactors each rated at 5MVA, 0.1p.u reactance. A generator of 8 MVA rating and 0.15 p.u reactance is connected to each section of the bus bar. Determine the S.C capacity of the breaker if a 3 phase fault takes place on one of the sections of the bus bar.

3. An alternator and a synchronous motor each rated for 50 MVA, 13.2 KV having sub transient of 20% are connected through a transmission link of reactance 10% on the base of machine ratings. The motor acts as a load of 30 MW at 0.8 p.f lead and terminal voltage 12.5 KV when a 3 phase fault takes place at the motor terminals. Determine the sub transient current in the alternator, the motor and the fault.

4. The per unit impedance matrix of a four bus power system shown in figure below,

$$Z_{Bus}=\begin{bmatrix} j0.15 & j0.075 & j0.14 & j0.135 \\ j0.075 & j0.1875 & j0.09 & j0.0975 \\ j0.14 & j0.09 & j0.2533 & j0.21 \\ j0.135 & j0.0975 & j0.21 & j0.2475 \end{bmatrix}$$

Calculate the fault current for a solid three symmetrical fault at bus 4. Also calculate the post fault bus voltages and line currents.

5. Explain symmetrical fault analysis using Z-bus matrix with neat flow chart. **(May 2011,Nov 2012 & May 2013, May 2014, May 2017, May 2018)**

6. A 3ϕ 5MVA 6.6 KV alternator with a reactance of 8% is connected to a feeder of series impedance 0.12+j0.48 Ω/Km. The transformer is rated at 3 MVA 6.6kV/33 KV and has a reactance of 5%.Determine the fault current supplied by the generator operating under no load with a voltage of 6.9 KV, when a 3ϕ symmetrical fault occurs at a point 15 Km along the feeder. **(May 2012, Nov, 2016 & May 2017, Nov 2020).**

7. The bus impedance matrix of 4-bus system with values in p.u is given by,

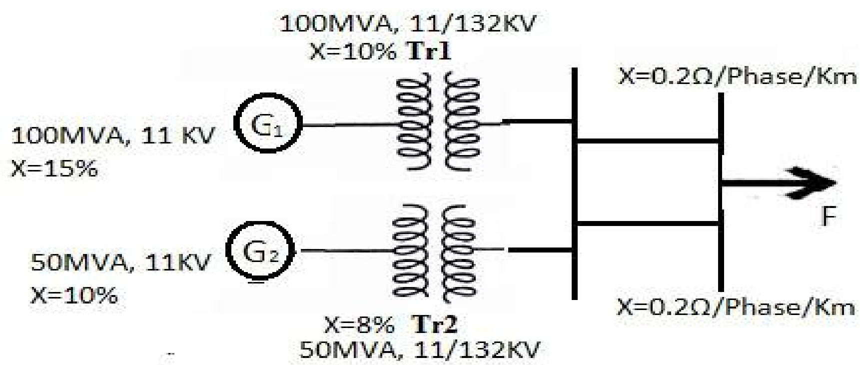
$$Z_{Bus} = j\begin{bmatrix} 0.15 & 0.08 & 0.04 & 0.07 \\ 0.08 & 0.15 & 0.06 & 0.09 \\ 0.04 & 0.06 & 0.13 & 0.05 \\ 0.07 & 0.09 & 0.05 & 0.12 \end{bmatrix}$$

In this system generator are connected to buses 1 and 2 and their sub transient reactances included when finding $Z_{Bus}$. If pre-fault current is neglected, find sub transient current in p.u in the fault for a 3-ph fault voltage as 1 p.u. If the sub transient reactance of generator in Bus 2 is 0.2p.u., find the sub transient fault current supplied by generator. **(May 2012)**

8. A synchronous generator and motor are rated 30 MVA, 13.2 KV and both have sub transient reactance of 20 %.The line connecting them has reactance of 10% on the base of machine ratings. The motor is drawing 20,000 KW at 0.8 p.f leading and terminal voltage of 12.8 KV when a symmetrical 3 phase fault occurs at the motor terminals. Find the sub transient current in the generator, motor and fault by using internal voltages of machines.**( May 2013, Nov 2015) (Nov/Dec 2020)**

9. A 11 KV, 100 MVA alternators having a sub –transient reactance of 0.25 p.u is supplying a 50 MVA motor having a sub –transient reactance of 0.2 p.u through a transmission line. The line reactance is 0.05 pu on a base of 100 MVA. Motor is drawing 40 MW at 0.8 power factor leading with a terminal voltage of 10.95 KV when a 3-phase fault occurs at the generator terminals. Calculate the total current in the generator and motor under fault conditions.**(Nov 2013, May 2011).**

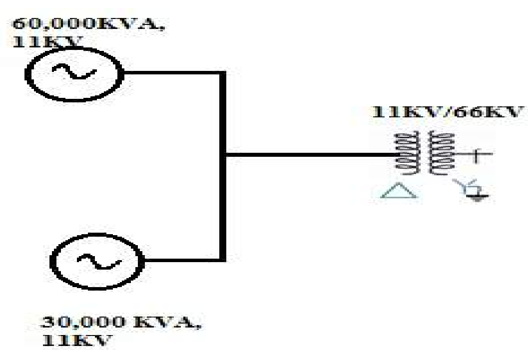
10. The figure shows a generating station feeding a 132 KV system. Determine the total fault current, fault level and fault current supplied by each alternator for a 3ϕ fault at the receiving end bus .The line is 200 Km long. Take a base of 100 MVA, 11 KV for LV side and 132 KV for HT side. **(Nov 2013, May 2016 & Nov 2017)**



11. A generator is connected through a five cycle circuit breaker to a transformer is rated 100 MVA,18 KV with reactances $X_d''$=20%,$X_d'$=25% and $X_d$= 110%. It is operated on no-load and at rated voltage. When a 3-phase fault occurs between the breaker and the transformer, find,

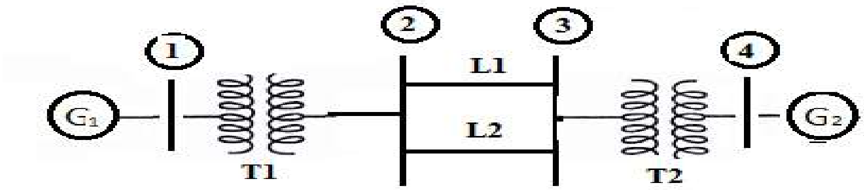
(i) Short circuit current in circuit breaker; (ii) The initial symmetrical rms current in the circuit breaker(iii) The maximum possible dc component of the short circuit current in the breaker;(iv)The current to be interrupted by the breaker;(v)The interrupting MVA **(May 2014)**

12.Two generators are connected in parallel to the low voltage side of a 3ϕ delta star transformer as shown in figure. Generator 1 is rated 60,000KVA, 11KV. Generator 2 is rated 30,000 KVA, 11Kv. Each generator has a sub transient reactance of $X_d''$= 25%. The transformer is rated 90,000 KVA at 11kv-Δ/66kv- Y with a reactance of 10%. Before a fault occurred, the voltage is unloaded and there is no circulating current between the generators. Find the sub transient current in each generator when a three phase fault occurs on the hv side of the transformer. **(May 2015)**



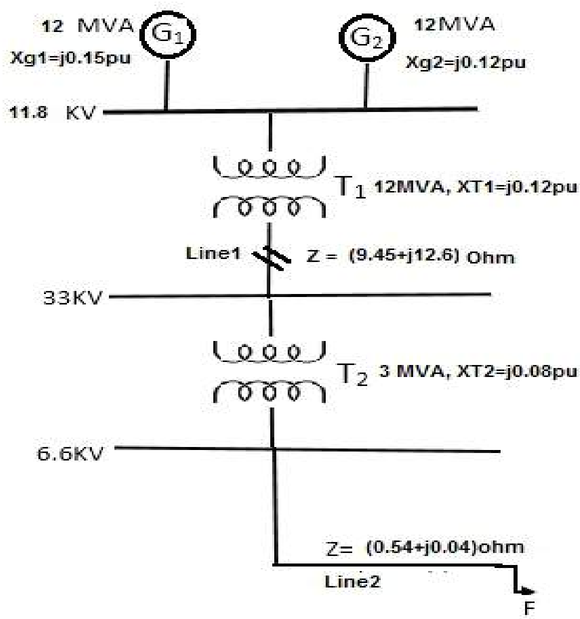

13. Generator G1 and G2 are identical and rated 11Kv, 20 MVA and have a transient reactance of 0.25pu at own MVA base. The transformer T1 and T2 are also identical and are rated 11/66KV, 5MVA and have a reactance of 0.06pu to their own MVA base. A 50km long transmission line is connected between the two generators. Calculate three phase fault current, when fault occurs at middle of the line as shown in figure. **(Nov 2015)**

14.A Symmetrical fault occurs at bus 4 for the system shown in Fig .Determine the fault current using Zbus Building algorithm.**(May 2016 & Nov 2017)**

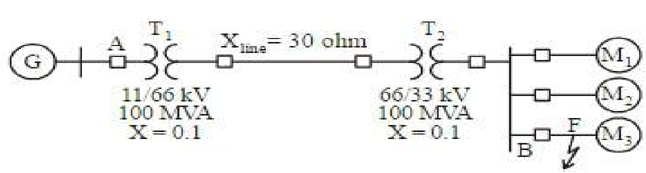



G1,G2: 100 MVA,20 KV,$X^+$=15%; Transformer: $X_{leakage}$=9%; L1,L2: $X^+$=10%

15. For the radial network shown in fig three phase fault occurs at point F. Determine the fault current and the line voltage at 11.8 KV bus under fault condition.**(Nov, 2016)**




16. A 100 MVA, 11 kV generator with X′′= 0.20 p.u is connected through a transformer and line to a bus bar that supplies three identical motor as shown in Fig and each motor has X′′= 0.20 p.u and X′= 0.25 p.uon a base of 20 MVA, 33 kV, the bus voltage at the motors is 33 kV when three phase balanced fault occurs at the point F. Calculate (i) Sub transient current in the fault (ii) Sub transient current in the circuit breaker B (iii) Momentary current in the circuit breaker B (iv) The current to be interrupted by C.B B in 5 cycles**.(May 2017)**



17. Construct Z Bus for the given network shown in figure 3. **(Nov 2018)**

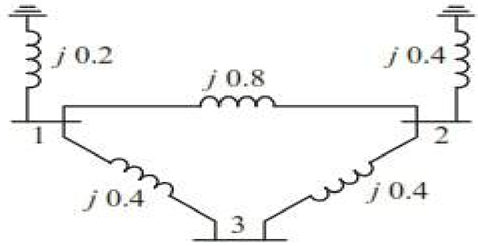



*Figure 3*

18. A 25 MVA, 11 kV generator with $X_d''$ = 20% is connected through a transformer, line and a transformer to a bus that supplies three identical motors as shown in figure 4. Each motor has $X_d''$ = 25% and $X_d'$ = 30% on a base of 5 MVA, 6.6 kV. The three-phase rating of the step-up transformer is 25 MVA, 11/66 kV with a leakage reactance of 10% and that of the step-down transformer is 25 MVA, 66/6.6 kV with a leakage reactance of 10%. The bus voltage at the motors is 6.6 kV when a three phase fault occurs at the point F. **(Nov 2018, April 2019)**

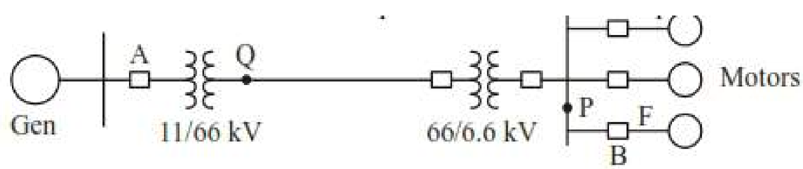



*Figure 4*

For the specified fault, calculate

(i) The subtransient current in the fault,

(ii) The subtransient current in the breaker

(iii) The momentary current in breaker B, and

(iv) The current to be interrupted by breaker B in five cycle.

19. Figure 7 shows a part of a power system, where the rest of the system at two points of coupling have been represented by their Thevenin's equivalent circuit (or by a voltage source of 1 pu together its fault level which corresponds to the per unit value of the effective Thevenin's impedance).

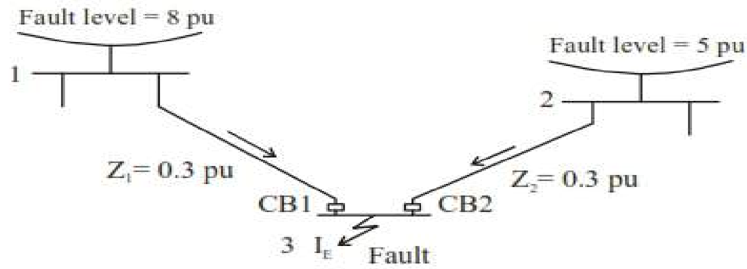



***Figure 7***

With CB1 and CB2 open, short circuit capacities are

SCC at bus 1 = 8 pu. gives $Z_{g1}$ = 1/8 = 0.125 pu

SCC at bus 2 = 5 pu gives $Zg2$ = 1/5 = 0.20 pu

Each of the lines are given to have a per unit impedance of 0.3 pu.

$Z_1 = Z_2 = 0.3$ pu.

Determine the fault current at bus 3. (**MAY 2018, NOV 2018).**

**20.** Describe the construction of Bus impedance matrix ($Z_{bus}$) using building algorithm for lines without mutual coupling.( **Nov/Dec 2019). (Nov/Dec 2020)**

**21.** A four bus sample power system is shown in fig. Perform the short circuit analysis for a three phase fault on bus 4 are given below.

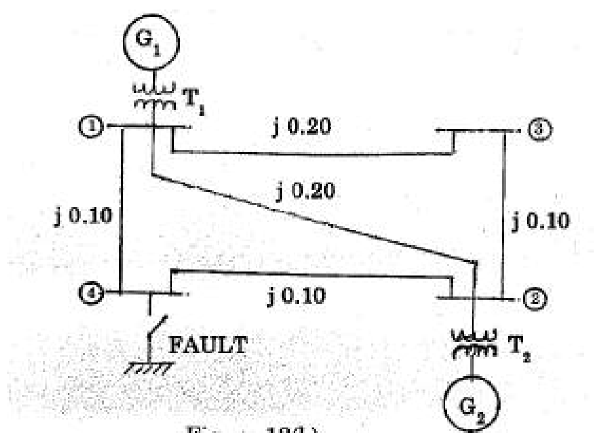
$G_1$ : 11.2kV, 100 MVA, X=0.08p.u.

$G_2$ : 11.2kV, 100 MVA, X=0.08p.u.

$T_1$ : 11/110kV, 100MVA, X=0.06p.u.

$T_2$ : 11/110kV, 100MVA, X=0.06p.u.

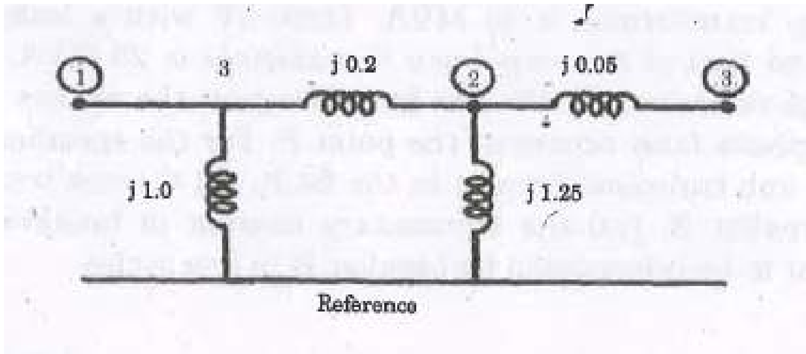
Assume pre fault voltages 1.0p.u. and pre-fault currents to be zero.( **Nov/Dec 2019).**




22. (i) Write a short notes on fault current in synchronous machine.

(ii) What are the assumptions made in fault analysis. (**April 2019).**

23. Construct Z bus using bus building algorithm. **(April 2019).**




## UNIT – IV FAULT ANALYSIS –UNBALANCED FAULT

### PART – A

**1. Name the faults involving ground.**

The faults involving ground are: single line to ground fault ii) double line to ground fault iii) Three phase fault

**2. Define positive sequence impedance.( Nov/Dec 2019).**

The positive sequence impedance of equipment is the impedance offered by the equipment to the flow of positive sequence currents.

**3. In which fault the negative and zero sequence currents are absent? (April 2019)**

In three phase fault the negative and zero sequence currents are absent.

**4. What are the boundary condition in line-to-line fault?**

The boundary condition for the line-to-line fault between the phases b and c is given below, $I_a=0$; $I_b+I_c=0$; $V_b=V_c$

**5. Write down the boundary condition in double line to ground fault?**

The boundary condition for the double line-to ground fault between the phases b and c to the ground is given below, $I_a=0$; $V_b=0$; $V_c=0$

**6. Give the boundary condition for the 3-phase fault.**

The boundary condition for the symmetrical three phase fault between tall the three phases given below, $I_a + I_b = I_c=0$; $V_a=V_b=V_c=0$

**7. Name the fault in which positive, -ve and zero sequence component currents are equal.(May 2012)**

In single line to ground fault the +ve, -ve and zero sequence component currents are equal.

**8.Write a short notes on Zero sequence network.**

The impedance or the reactance diagram formed by using zero sequence impedance is called Zero sequence network.

**9.Write a short notes on negative sequence network.**

The impedance or the reactance diagram formed by using negative sequence impedance is called Negative sequence network.

**10.Write a short notes on positive sequence network.**

The impedance or the reactance diagram formed by using positive sequence impedance is called Positive sequence network.

**11.How will you express positive, negative and zero – sequence impedances of Y – connected loads?**

Positive sequence impedance $Z^1 = Z_s + 3Z_n + 2Z_m$.

Negative sequence impedance $Z^2 = Z_s - Z_m$

Zero sequence impedance $Z^0 = Z_s - Z_m$ Where, $Z_s$ = self impedance of Y – connected load, $Z_n$= load neutral impedance $Z_m$ = Mutual impedance.

**12. Define unsymmetrical fault.**

The fault is called unsymmetrical fault if the fault current is not same in all the three phases.

**13. What is sequence network? (May 2011, Nov 2014)**

The network which is used to represent the positive, negative and zero sequence components of unbalanced system is called as sequence network

**14. What are the symmetrical components of a three phase system? (May 2011, Nov 2012, Nov 2014, Nov 2015, May 2016 & Nov 2018)**

The symmetrical components are used to represent unbalanced quantities, they are

1) Positive sequence
2) negative sequence
3) Zero sequence

**15. What is meant by a Fault? (May 2012)**

A fault in a circuit is any failure which interferes with the normal flow of current .The faults are associated with abnormal change in current, voltage and frequency of the power system. The faults may cause damage to the equipment if it is allowed to persist for a long time.

**16. List the various symmetrical and unsymmetrical faults in a power system. (May 2012, Nov/Dec 2019).**

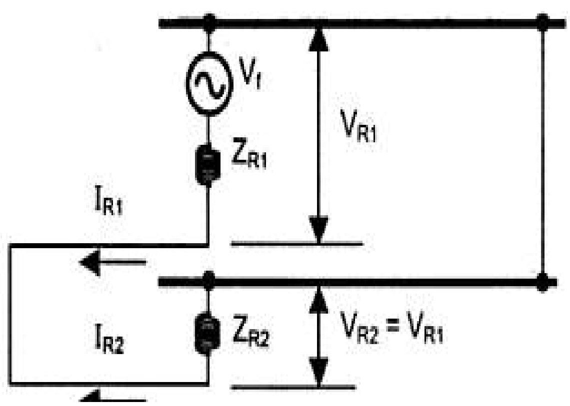
**Symmetrical fault:** 3 phase short circuit fault.

**Unsymmetrical fault:** i) single line to ground fault ii) line to line fault iii) double line to ground fault iv) open conductor fault

**17. Define negative sequence impedance? (May 2013)**

The negative sequence impedance of an equipment is the impedance offered by the equipment to the flow of negative sequence current.

**18. Draw the sequence network connections corresponding to L-L fault at bus. (May 2013)**




**19. What are the observations made from the analysis of various faults? (Nov 2013)**

i) To check the MVA ratings of the existing circuit breakers, when new generation are added into a system; ii) To select the rating for fuses, circuit breaker and switch gear in addition to setting up of protective relays; iii) To determine the magnitudes of currents flowing throughout the power system at various time intervals after a fault occurs.

**20. Write the boundary conditions for single line to ground fault. (Nov 2013)**

The boundary condition for the single line to ground fault between the phase a to the ground is given as, Va = 0; $I_b=I_c=0$

**21. What are the features of zero sequence current?(May 2014 & Nov 2017)**

As zero sequence currents in three phases are equal and of same phase, three systems operate like single phase as regards zero sequence currents. Zero sequence currents flow only if return path is available through which circuit is completed.

**22. Write the symmetrical component current of phase 'a' in terms of 3ϕ currents. (May2016, Nov 2018)**

$$I_{a0} = \frac{1}{3}[I_a + I_b + I_c] \qquad I_{a1} = \frac{1}{3}[I_a + aI_b + a^2I_c] \qquad I_{a2} = \frac{1}{3}[I_a + a^2I_b + aI_c]$$

**23. State the reason why, the negative sequence impedance of a transmission line is taken as equal to positive sequence impedance of the line. (May 2015).**

A transmission line is a passive and bilateral device. By passive, we mean there are no voltage or current sources present in the equivalent model of a transmission line. Bilateral means the line behaves the same way regardless of the direction of the current. Note that although a single transmission line is bilateral. Because of a transmission line's passive and bilateral properties, the phase sequence of the applied voltage makes no difference, as a-b-c (positive-sequence) voltages produce the same voltage drops as a-c-b (negative-sequence) voltages. This means that the positive- and negative-sequence impedances of a transmission line are identical, provided that the line is transposed.

**24. What is sequence Operator? (Nov 2015)**

In balanced problem, to find the relationship between phase voltages and phase currents, we use sequence operator. An operator which will turn a phasor through 120 degree in three phase problems. This operator is called as ' a ' operator.

**25. Why the neutral grounding impedance $Z_n$ appears as $3Z_n$ in zero sequence equivalent circuit? (Nov 2016)**

If the neutral of a transformer is grounded through a grounding impedance Z¯ n, then, the total zero-sequence equivalent impedance to be used in the equivalent circuit is Z¯ 0 total = Z¯ 0 + 3Z¯ n . This is due to the fact that the neutral current is 3 times the zero-sequence current per phase.

**26. Express the unbalanced voltages in terms of symmetrical components. (May 2017)**

$V_a = [V_{a0} + V_{a1} + V_{a2}]$

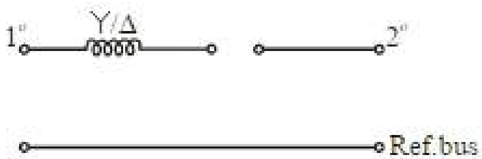
$V_b = [V_{a0} + aV_{a2} + a^2V_{a1}]$

$V_c = [V_{a0} + a^2V_{a2} + aV_{a1}]$

Where, $V_a$, $V_b$, $V_c$– Unbalanced phase voltages

$V_{a0}$, $V_{a1}$, $V_{a2}$ – Symmetrical components of phase'a'

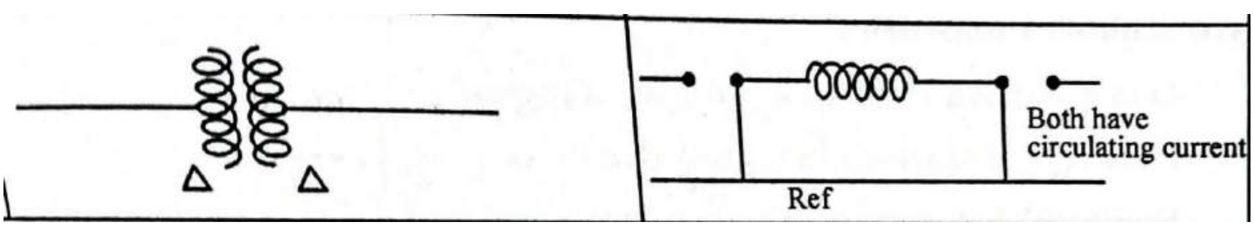
**27. Draw the zero-sequence network of Y/Δ transformer with neutral ungrounded. (May 2017)**




**28. Explain the concept of sequence impedances and sequence networks.**

Sequence impedances and sequence networks are the fault analyzing and calculating parameters in power system networks. Sequence impedances are of three types. They are positive, negative and zero sequence impedances. The sequence impedances are the impedances offered by the device or components to respective sequence current. The single phase equivalent circuit of power system formed using impedance of any one sequence only is called sequence circuit or sequence network.

**29. Draw the zero sequence impedance equivalent circuit for Δ-Δ type three phase transformers. April 2019**




**30. What are the advantages of symmetrical components? (Nov/Dec 2020)**

Symmetrical components are balanced phasor. They are used to represent the unbalanced phasor. Very complex unbalanced phasor analysis can be performed easily by using symmetrical components. Systematic computer analysis is possible using symmetrical components.

**31.Name the faults in which zero sequence currents are absent. (Nov/Dec 2020)**

The faults in which zero sequence currents are absent are Line-to-Line fault and Three-phase fault.

## PART – B

1. Develop the expressions for analyzing double line to ground fault in a large power system using Zbus matrix.

2. A 50Hz, 13.2 KV, 15MVA alternator has X1=X2=20% and X0=8% and the neutral is grounded through a reactor of 0.5ohm. Determine the initial symmetrical rms current in the ground reactor when a double line to ground fault occurs at the generator terminals at a time when the generator voltage was 12KV.

3. Derive the necessary equations for calculating the fault current and bus voltages for a single line to ground fault.

4. A 3-phase, 10 MVA, 11KV, generator with solidity earthed neutral point supplies a feeder. The relevant impedances of the generator and feeder in ohm are as below:

| | Generator | Feeder |
|---|---|---|
| (a) +ve sequence | j1.2 | j1.0 |
| (b)-ve sequence | j0.8 | j1.0 |
| (c) zero sequence | j0.4 | j3.0 |

If the line to line fault occurs at the far end of the feeder, calculate the fault current.

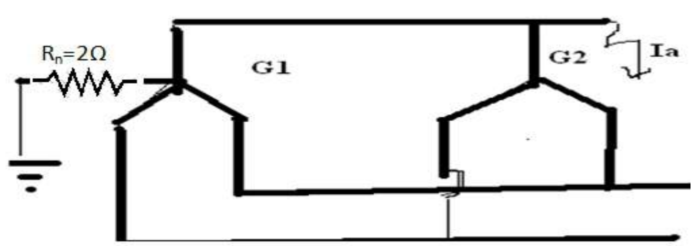
5.A salient pole generator is rated 20 MVA, 13.8 kV and has X1=0.25p.u X2=0.35p.u and X0=0.1p.u. The neutral of the generator is solidly grounded. Compute fault current in the generator and line to line to ground fault at its terminals. Neglect initial load on the generator. The reactance of a generator are X''=X2=0.15p.u and X0=0.05p.u. The generator ratings are 10 MVA, 6KV. The generator is star connected with neutral point grounded through a reactor of 0.5ohm reactance. Compute fault current in amps when a single line to ground fault occurs at the generator terminals.

6. Two 25 MVA, 11KV synchronous generators are connected to a common bus bar which supplies a feeder. The star point one of the generators is grounded through a resistance of 1 ohm and that of the other generator is isolate. A line to ground fault occurs at the far end of the feeder. Determine the fault current.

7. Develop the expressions for analyzing single line to ground fault in a large power system using Zbus matrix.

8. What are the assumptions made in short circuit studies? Deduce and show the sequence network for a line to line fault at the terminals of a unloaded generator. (May 2011, May 2016 & Nov 2017, Nov / Dec 2019)

9. Two 11KV, 20MVA .Three phase star connected generators operate in parallel as shown in figure. The positive, negative and zero sequence reactance are j0.18,j0.15,j0.10pu. The star point of one of the generator is isolated and that of the other is earthed through 2.0 ohms resistor. A single line to ground fault occurs at the terminals of one of the generators. Estimate i) Fault current ii) current in the grounding resistor and iii)the voltage across the grounding resistor.(May 2011& May 2017, Nov 2020)




10. Derive the necessary equation to determine the fault current for a single line to ground fault. Draw a diagram showing the interconnections of sequence networks. (May 2012 & Nov 2017, Nov 2020)

11. A 11 kV, 30MVA alternator has Z1=Z2=-j0.2 pu and Z0=-j0.05 pu. A line to ground fault occurs on the generator terminals. Determine the fault current and line to line voltages during faulted conditions. Assume that the generator neutral is solidly grounded and the generator is operating at no load and at the rated voltage during the occurrence of the fault. (May 2012, Nov 2016)\

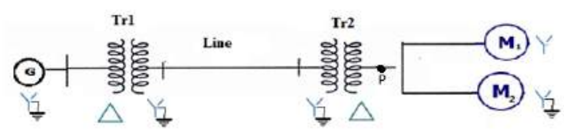
12. A 50 MVA 11 KV alternators were subjected to different types of faults. The faults are 3ϕ fault 1870A, Line to Line Fault 2590A, Single line to ground fault 4130 A. The alternator neutral is solidly grounded. Find the per unit values of the three sequence reactance of an alternator. (May 2012).

13.Draw the sequence network connection for a double line to ground fault at any point in a power system and from that obtain an expression for the fault current.(Nov 2012, May 2016 & Nov 2017, April / May 2019)

14. Derive an expression for the total power in a three phase system in terms of sequence components of voltages and currents. (ii) Discuss in detail about the sequence impedances of transmission lines.(Nov 2012 & Nov 2015)

15. Discuss in detail about the sequence impedances and networks of synchronous machines, transmission lines, transformers and load. (May 2013)

16. A single line diagram of a power network is shown in the figure. (May 2013)



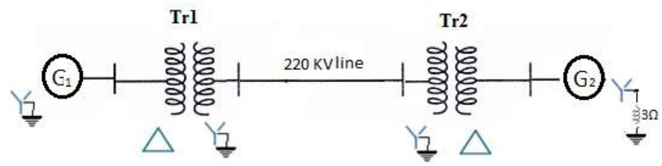

The system data is given in the tables below:

| Element | Positive sequence reactance | Negative sequence reactance | Zero sequence reactance |
|---|---|---|---|
| Generator G | 0.1 | 0.12 | 0.05 |
| Motor M1 | 0.05 | 0.06 | 0.025 |
| Motor M2 | 0.05 | 0.06 | 0.025 |
| Transformer Tr1 | 0.07 | 0.07 | 0.07 |
| Transformer Tr2 | 0.08 | 0.08 | 0.08 |
| Line | 0.10 | 0.10 | 0.10 |

Generator grounding reactance is 0.5 pu. Draw sequence networks and calculate the fault for a line to line fault on phase b and c at point P. Assume 1.0 pu pre fault voltage throughout.

17. The figure shows the power system network. Draw zero sequence network for this system. The system data is as under.

Generator G1:50 MVA ,11 KV, X0= 0.08 pu Transformer T1 :50 MVA,11/220 KV, X0= 0.1pu, Generator G2 :30 MVA ,11 KV, X0= 0.07pu Transformer T2 ;30 MVA ,11/220 KV ,X0= 0.09 pu, Zero sequene reactance of line is 555.6 Ω. Choose base MVA 50 and base voltage 11 KV for LT side and 220 KV for HT side.(Nov 2013)




18. A 25 MVA, 13.2 KV alternator with solidly grounded neutral has a sub transient reactance of 0.25 p.u. The negative and zero sequence reactance are 0.35 and 0.01 p.u. respectively. If a double line-to-ground fault occurs at the terminals of the alternator, determine the fault current and line to line voltage at the fault. (May 2014)

19. Obtain the expression for fault current for a line to line fault taken place through an impedance Zf in a power system. (Nov 2013 & May 2014) (May 2016, Nov 2016 & May 2017, Nov 2018, Nov 2020)(Nov/Dec 2020)

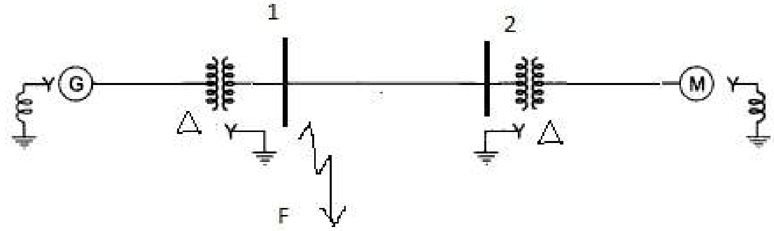
20. Explain about the concepts of symmetrical component. (Nov 2014)

21.A single line to ground fault occurs on Bus 1 of the system of the fig. shown below. Find

i) Current in the fault

ii) SC current in phase A of generator

iii) Voltage of the healthy phases of the bus1 using Z bus method



Given: Rating of the each machine 1200KVA, 600V,with X=X2=10%,Xo=5% each three phase transformer is rated 1200 KVA , 600V-Δ/3000V-Y with leakage reactance of 5% the reactance of the transmission line are X1 = X2 =20% and Xo=40% on the base of 1200 KVA ,3300V,the reactance of the neutral reactors are 5% on the KVA and voltage base of the machine.(Nov 2014)

22. A 30 MVA, 11Kv, 3ϕ synchronous generator has a direct sub transient reactance of 0.25 pu. The negative and zero sequence reactance are 0.35 and 0.1pu respectively. The neutral of the generator is solidly grounded. Determine the sub transient current in the generator and the line to line voltages for sub transient conditions when a single line to ground fault occurs at the generator terminals with the generator operating unloaded at rated voltages. (Nov 2015)

23. A 3 phase salient pole synchronous generator is rated 30 MVA, 11kV and has a direct axis sub transient reactance of 0.25 p.u. The negative and zero sequence reactances are 0.35 and 0.1 p.u respectively. The neutral of the generator is solidly grounded. Calculate the sub transient current in the generator when a line to line fault occurs at the generator terminals with generator operating unloaded at rated voltage. (May 2017)

24. A single line to ground fault (on phase a) occurs on the bus 1 of the system of Figure shown figure 5.

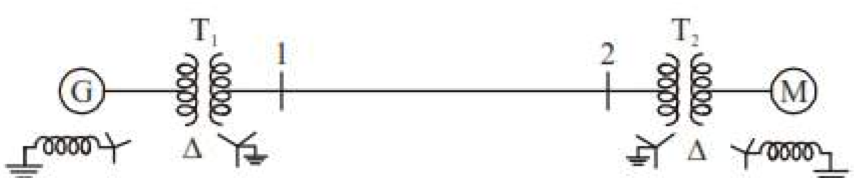



***Figure 5***

Using bus impedance (Zbus) method Find

(i) Current in the fault.

(ii) SC current on the transmission line in all the three phases.

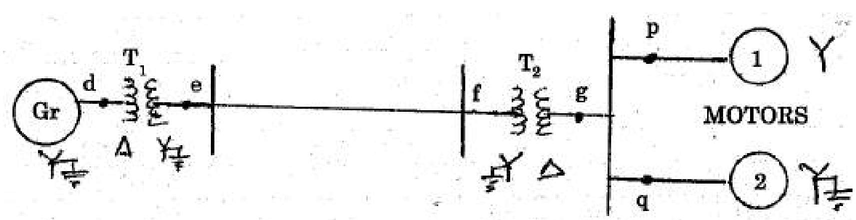
(iii) SC current in phase ‘a’ of the generator.

(iv) Voltage of the healthy phases of the bus 1.

Given: Rating of each machine 1200 kVA, 600 V with X1 = X2 = 10% , X0 = 5%. Each three-phase transformer is rated 1200 kvA. 600/3300v (Delta/Star) with leakage reactance of 5%. The reactances of the transmission line are X1 = X 2=20% and X0 = 40% on a base of 1200 kVA, 3300 V. The reactance's of the neutral grounding reactors are 5% on the kVA and voltage base of the machine. (NOV 2018)

25) The reactance of an alternator rated 10 MVA, 6.9 kV are $X_1 = X_2 = 15\%$ and $X_{g0} = 5\%$. The neutral of the alternator is grounded through a reactance of 0.38 ohm. Single line to ground fault occurs at the terminals of the alternator. Determine the line currents, fault current and the terminal voltages. **(April / May 2019)**

26) A 50 MVA, 11 kV synchronous generator has a sub-transient reactance of 20%. The generator supplies two motors over a transmission line with transformers at both ends as shown in figure. The motors have rated inputs of 30 and 15MVA, both 10 kV, with 25% sub transient reactance. The three phase transformers are both rated 60 MVA, 10.8 / 121 kV with leakage reactance of 10% each. Current limiting reactors of 2.5 ohms each connected in the neutral of the generator and the motor number 2. The zero-sequence reactance of the transmission line is 300 ohms. The series reactance of the line is 100 ohms. Draw the positive, negative and zero sequence networks. **(Nov / Dec 2019)**

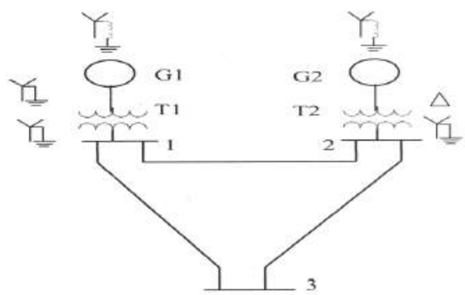



Consider base 50 MVA and 11kV are the base values from the generator side and compute per unit values for positive, negative and zero sequence values.

27) Show that positive and negative sequence currents are equal in magnitude but out of phase by 180 deg. in a line-to-line fault. **(Nov 2020)**

**28.** The one line diagram of a simple power system is shown in fig. The neutral of each generator is grounded through a current-limiting reactor of0.25/3 pu on a 100 MVA base. The system data expressed in per unit on a common 100 MVA base is tabulated below. The generators are running n no-load at their rated voltage and rated frequency with their emfs in phase. Using bus impedance matrix determine the fault current for a single line to ground fault at bus 3 through a fault impedance $Z_f$ = j0.1 pu. Also determine the bus voltages and line currents during fault. **(Nov/Dec 2020)**

| Element | Base MVA | V-rating | $X_1$ | $X_2$ | $X_0$ |
|---|---|---|---|---|---|
| G1 | 100 | 20 kV | 0.15 | 0.15 | 0.05 |
| G2 | 100 | 20 kV | 0.15 | 0.15 | 0.05 |
| T1 | 100 | 20/220 kV | 0.1 | 0.1 | 0.1 |
| T2 | 100 | 20/220 kV | 0.1 | 0.1 | 0.1 |
| L12 | 100 | 220 kV | 0.125 | 0.125 | 0.3 |
| L13 | 100 | 220 kV | 0.15 | 0.15 | 0.35 |
| L23 | 100 | 220 kV | 0.25 | 0.25 | 0.7125 |




29. A single line to ground fault (phase a) occurs in a transmission system at transformer T1 star terminal. Draw the sequence network. Find current fed to fault.

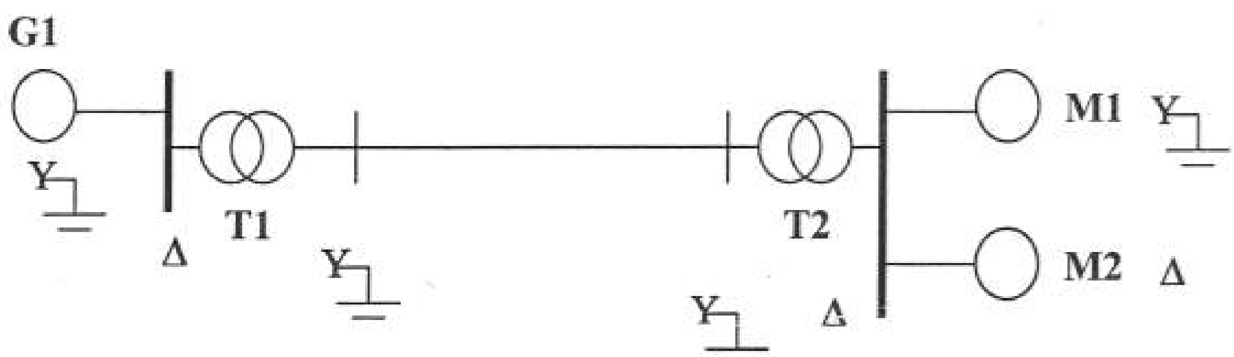
Given:

Rating of generator is 1200 kVA with X' = X2 = 10%, . X0 = 5%

Rating of each machine is 600 kVA, 600 V with X'=X2 = 12%, . X0 = 6%

Each transformer is rated 1200MVA, 600 V on delta side and 3.3 kV on star side, with leakage rectance of 5%.

Reactance of the transmission line isX1 = 10%, X2= 10%, X0=20%. **(Nov/Dec 2020)**




## UNIT–V STABILITY ANALYSIS

## PART – A

**1. Define Dynamic stability of a power system.**

Dynamic stability is the stability given to an inherently unstable system by automatic control devices and this dynamic stability is concerned with small disturbances lasting for times of the order of 10 to 30 seconds.

**2. Define the inertia constants M & H.**

Angular momentum (M) about a fixed axis is defined as the product of moment of inertia about that axis and the associated angular velocity. $M = I.\ \omega$ watt/rad/Sec$^2$.Inertia constant (H) is the K.E in Mega joules to the three phase MVA rating of the machine.

**3. Define load angle of a generator**.

Load angle:- This is the angle between the generated e.m.f or the supply voltage (E ) and the terminal voltage. This angle is also called as torque or power angle of the machine.

**4. State equal area criterion of stability. (May 2017 & Nov 2017), Nov/Dec 2019**

The system is stable if the area under accelerating power (Pa) - δ curve reduces to zero at some value of δ. In other words, positive area under Pa -δ curve must be equal to the negative area and hence the name equal area criterion of stability.

**5. What are limitations of equal area criterion?**

The limitations of equal area criterion are: i) The critica clearing time cannot be calculated even though the critical clearing angle is known. Hence numerical methods such as Runge-kutta method, point by point or Euler's method are employed. ii) It's a more simplified approach.

**6. If two machines with inertia's $H_1$, $H_2$ are swinging together, what will be the inertia of the equivalent machine?**

$$H_s = \frac{H_1 G_1 + H_2 G_2}{G_s}$$

$H_1$ and $H_2$ is the Inertia constant of $M_1$ and $M_2$; $G_1$ and $G_2$ is the capacity of $M_1$ and $M_2$.

$H_s$ is the equivalent inertia of $M_1$ and $M_2$ ; $G_s$ is the equivalent capacity of $M_1$ and $M_2$.

**7. On what basis do you conclude that the given synchronous machine has lost stability?**

Following a sudden disturbance on a power system rotor speeds, rotor angular differences and power transfer undergo fast changes whose magnitude is dependent on the severity of the disturbance. If these disturbances leads to growing oscillations in the power system even after some period of time say more than 30 seconds then system said are in asynchronous state and it has lost synchronism.

**8. On what a factor does the critical clearing angle depends.**

The critical clearing angle depends upon the clearing time, which depends upon auto closing/reclosing and opening of circuit breakers.

**9. Define steady state stability limit. (Nov 2014), Nov/Dec 2019.**

It is the maximum power that can be transferred without the system becoming unstable when the system is subjected to small disturbances.

10. **Mention methods of improving stability limit. (Nov 2016, Nov 2018, Nov 2020)**

The steady state stability limit can be increased by i) Reducing the X, in case of transmission lines by using double circuit lines. ii) Use of series capacitors to get better voltage. iii) Higher excitation systems and quick excitation system are employed.

The following methods are employed to increase the transient stability limit of the power system- (i)Increase of system voltages, (ii) use of AVR. (iii) Use of High speed excitation systems. (iv) Reduction in transfer reactance. (v) Use of high speed reclosing breakers.

**11. A 50Hz, 4 pole turbo alternator rated at 20 MVA, 13.2 KV has as inertia constant H = 4 KW –sec/ KVA. Find the K.E stored in the rotor at synchronous speed.**

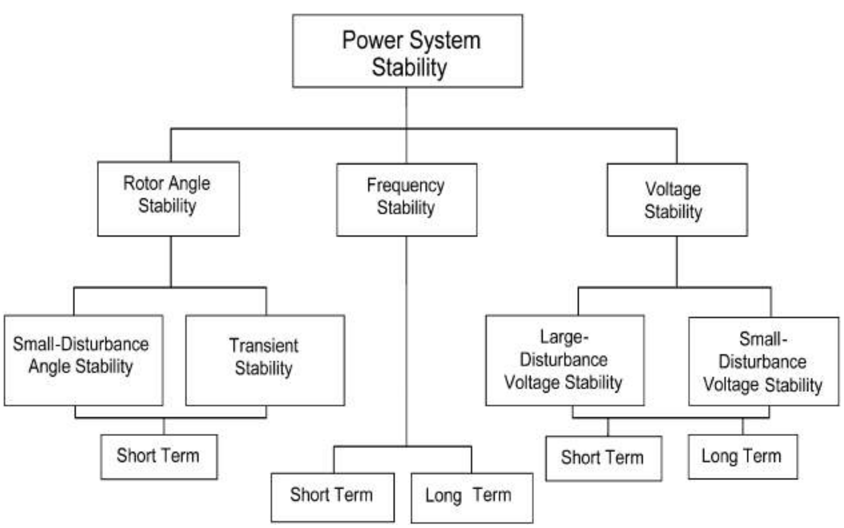
F = 50Hz. P = 4, G = 20 MVA, H = 4 KW – Sec/ KVA.

Stored K.E = 4 x 20 = 80MJ.

**12. Mention the methods used for the solution of swing equation.**

Methods used for solution of swing equation are: Point by point method, Modified Euler's method and Runge-kutta method.

13. **How is the power system stability classified? (May 2015)**



**14. What are Coherent Machines? (Nov 2018, Nov 2020)**

Two synchronous machines with similar parameters swinging together are called as coherent machines. This is very much used in multi machine stability analysis.

**15. What are the applications of equal area criterion?**

(i) Switching operation. (ii) Fault and subsequent circuit isolation. (iii) Fault, circuit isolation and reclosing

**16. What are the classifications of angle stability?**

Small signal stability (steady state) and transient stability (large signal).Small signal is further classified as Oscillatory and Non oscillatory stability. Oscillatory includes Inter area mode, control mode and Torsional mode

**17. Define critical clearing angle and time? (May 2011, May 2012, Nov 2012, Nov 2014, May 2015, April 2019) or State the significance of critical clearing time. (Nov/Dec 2020)**

**Critical clearing angle '$\delta_c$':**

The critical clearing angle is defined as the maximum change in the load angle curve before clearing the fault without loss of synchronism. In other words, when the fault occurs in the system the load angle curve begin to increase, and the system becomes unstable. The angle at which the fault becomes clear and the system becomes stable is called critical clearing angle.

**Critical clearing time '$t_c$':**

If any fault occurs in a system, which leads to increase in the load angle, and if it is not cleared before critical clearing time, then the system becomes unstable. The time at which the fault becomes clear before losing the synchronism is nothing but critical clearing time.

**18. Write swing equation (May 2011)**

$P_m - P_e = M d^2\delta/dt^2$

Where, $P_m$- Input Mechanical power, $P_e$– output electrical power, M- Angular momentum

**19. Define transient stability and stability limit. (May 2012, Nov 2017, May 2018)**

The **transient stability** is defined as the ability of a power system to return to stable operation when it is subjected to a large disturbance. The maximum power that can be transferred through the system during a very large disturbance without loss of synchronism is called **transient stability limit**.

**20. Distinguish between steady state and transient state stability. (Nov 2012)**

Steady state stability is basically concerned with the ability of the system to restore back to its stable state upon a small disturbance whereas the transient stability is concerned with large disturbances.

**21. What is meant by power angle curve? (May 2013 & Nov 2015)**

The graphical plot of real power versus power/torque angle is called as power angle curve.

$P_e = P_m \sin\delta$.    $P_m = E_1E_2 / X$.

**22. Define Infinite bus in power system. (Nov 2012 & May 2013), April 2019**

The capacity of a system comprising of many machines is so large, that its voltage & frequency may be taken as constant. The connection or disconnection of a single machine does not change the |V| and frequency. Such a constant voltage and frequency system is called as Infinite bus.

**23. Differentiate between voltage stability and rotor angle stability. (Nov 2013, Nov 2016)**

Voltage stability is the ability of a power system to maintain steady acceptable voltage at all buses in the system under normal operating conditions and after being subjected to a disturbance.

Rotor angle stability is the ability of interconnected synchronous machines of a power system to remain in synchronism.

**24. Define swing curve? What is the use of this curve? (Nov 2013, May 2017)**

A graph of power angle '$\delta$' versus time 't' in seconds is called **swing curve**. The stability of the machine is calculated by using swing curve. This curve is obtained by solving the swing equation of the machine. The critical angle and critical clearing time is calculated by using swing curve.

**25. Define dynamic stability (May 2014)**

The dynamic stability study is concerned with the study of nature of oscillations and its decay for small disturbances.

**26. Find the frequency of oscillation for a synchronizing co-efficient of 0.6, inertia constant H= 4 and system frequency of 50 Hz. (May 2014)**

Frequency of oscillation = $\sqrt{\frac{C}{M}}$; $M = \frac{H}{\pi f} = \frac{4}{\pi X 50} = 0.0255$ p.u

Frequency of oscillation = $\sqrt{\frac{0.6}{0.0255}} = 4.85\,\frac{rad}{sec} = \frac{4.85}{2\pi} = 0.7719\ Hz$

**27. A four pole , 60 Hz synchronous generator has a rating of 200 MVA, 0.8 power factor lagging. The moment of inertia of the motor is 45,100kg-m$^2$. Determine M and H. (Nov 2015)**

**Solution.**

**Ns=** $\frac{120f}{p}$ **= 1800rpm,**

**$n_s$= Ns/60 = 30 rps, $\omega_s = 2\pi n_s$= 188.4**

**Kinetic Energy=**$\frac{1}{2}J\omega_s^2$ **=** $\frac{1}{2}x45000x188.4^2 = 798627600J = 798.62MJ$

**Inertia Constant H =** $\frac{KE}{G} = \frac{798.62}{200} = 3.99.MJ/MVA$

**M=**$\frac{GH}{180xf} = \frac{KE}{180xf} = \frac{798.62}{180x60} = 0.073946MJ\ \text{sec}/\ Electrical\ \text{deg}\,ree$

**28.Define Rotor angle stability. (Nov/Dec 2020)**

Rotor angle stability is the ability of the interconnected synchronous machines running in the power system to remain in the state of synchronism. Two synchronous generators running parallel and delivering active power to the load depends on the rotor angle of the generator (load sharing between alternators depends on the rotor angle).

## PART B

1. A 50Hz generator is supplying 60% of $P_{max}$ to an infinite bus through a reactive network. A fault occurs which increases the reactance's of the network between the generator internal voltage and infinite bus by 400%. When the fault is cleared, compute the max value of critical clearing angle by applying equal area criteria.

2. Explain the importance of stability analysis in power system. **(Nov 2017, Nov 2013, Nov 2017, May 2018, May 2018).**

3. A motor is receiving 30% of the power that it is capable of receiving from an infinite bus. If the load on the motor is doubled. Calculate the max value of $\delta$ during the swinging of the rotor around its new equilibrium position. **(Nov 2015, Nov 2020).**

4. Describe the Runge-Kutta method of solution of swing equation for multi machine systems. **(May 2011 & May 2017, NOV 2018)**

5. Derive the Power angle equation for a i) SMIB system and also draw the power angle curve.**(May 2012)** What are the techniques available to improve steady state stability? **(May 2015, Nov 2013, May 2016, May 2017 & Nov 2017)**

6. Using Equal area criterion derive an expression for critical clearing angle for a system having a generator feeding a large system through a double circuit line. **(May 2012, Nov 2014 & Nov 2017) (Nov/Dec 2020)**

7. A 3 phase generator delivers1.0 pu power to an infinite bus through a transmission network when fault occurs. The maximum power which can be transferred during pre-fault, during fault and post fault condition are 1.75pu, 0.4pu and 1.25 pu. Find the critical clearing angle. **(May 2012).**

8. (a) State and explain the equal area criterion. (b) Indicate how you will apply equal area criterion. (i) To find the max additional load that can be suddenly added. (ii) In a two-circuit transmission system sudden loss of one circuit. **(Nov 2012) (May 2013)**

9. Derive the swing equation of a synchronous machine swinging against an infinite bus. Clearly state the assumptions made in deducing the swing equation. State the usefulness of this equation. State the reasons for its nonlinearity and extend the derivation for two parallel connected coherent and incoherent machines. **(May 2014, May 2013, Nov 2014, Nov 2015, Nov, 2016, May 2018, Nov 2018, April / May 2019, Nov / Dec 2019, Nov 2020).**

10. Explain the terms critical clearing angle and critical clearing time in connection with the transient stability of a power system. **(May 2011& Nov 2017)**

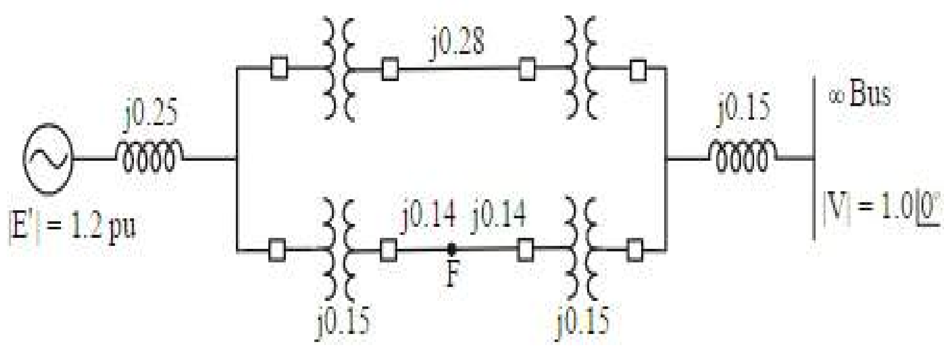
11. Describe the algorithm for modified Euler method of finding solution for power system stability problem studies. **(Nov 2012, May 2014, May 2016 & Nov 2017, NOV 2018).**

12. The moment of inertia of a 4 pole, 100 MVA, 11Kv, 3ϕ, 0.8 power factor, 50 Hz turbo alternator is 10000kg-$m^2$. Calculate H and M. **(Nov 2015).**

13. A Generator is operating at 50 Hz, delivers 1.0 p.u 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 p.u. Before the fault, this power was 2.0 p.u. and after the clearance of fault it is 1.5 p.u. By the use of equal area criterion, determine the critical angle**. (May 2016 & Nov 2017)**

14. Find the critical clearing angle and time for clearing the fault with simultaneous opening of the breakers when a three-phase fault occurs at point P close to bus 1 as shown in fig. The generator is delivering 1.0p.u power at the instant preceding the fault. **(Nov, 2016, May 2018)**

15. Find the critical clearing angle of the system shown in Fig, for a 3-phase fault at the point 'F'. The generator is delivering 1.0 p.u. power under pre fault conditions**. (May 2017, Nov / Dec 2019)**




16. The per unit system reactances that are converted in a common base, are shown in this figure 6. Let us assume that the infinite bus voltage is 1.0. The generator is delivering 1.0 per unit real power at a lagging power factor of 0.9839 to the infinite bus. While the operator is operating in state, a three-phase bolted short circuit occurs in the transmission line connecting buses 2 and 4 – very near to bus 4. The fault is cleared by

opening the circuit breakers at the two ends of this line, find the critical clearing time for various values of H. **(NOV 2018, Nov 2020)**

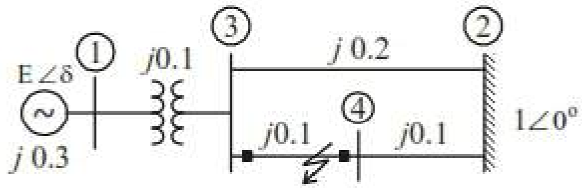
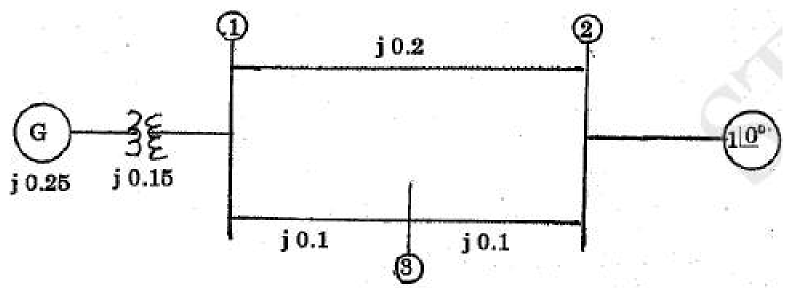



***Figure 6***

17. a 4-pole, 50 Hz. 11 kV turbo generator is rated 75 MW and 0.86 power factor lagging. The machine rotor has a moment of inertia of 9000 Kg-$m^2$. Find the inertia constant in MJ/MVA and M constant or momentum in MJs/elec degree. **(April / May 2019)**

18) A single line diagram of a system is shown in figure. All the values are in per unit on a common base. The power delivered into bus 2 is 1.0 pu at 0.8 power factor lagging. Obtain the power angle equation and the swing equation for the system. neglect all losses. **(Nov / Dec 2019)**




19. Discuss the procedure for solving the swing equation using modified- Euler method. **(Nov/Dec 2020)**

20. Fig shows transmission network. The pu reactances of the equipments are as shown. The voltage behind reactance of generator is 1.1pu. The system is transmitting 1 pu real power when fault occurs at the middle of one of the line. Determine:

i) Transfer reactance for prefault, during fault and post fault conditions and

ii) Critical clearing angle for the fault at the mid-point of the line. **(Nov/Dec 2020)**