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Degree/ Branch: B. E / EEE **Semester/ Year: V/ III**

Subject Code / Name: EE8501/ POWER SYSTEM ANALYSIS

(Question Bank)

UNIT-I POWER SYSTEM

Part A (2 marks for each question)

1. Explain the requirements of planning the operation of a power system.

Planning the operation of a power system requires load studies, fault calculations, the design of means for protecting the system against lightning and switching surges and against short circuits, and studies of the stability of the system.

2. Define steady state operating condition.

A power system is said to be in a steady state operating condition, if all the measured (or calculated) physical quantities describing the operating condition of the system can be considered constant for the purpose of analysis.

3. What is a disturbance and what are the two types of disturbances?

If a sudden change or sequence of changes occurs in one or more of the system parameters or one or more of its operating quantities, the system is said to have undergone a disturbance from its steady state operating condition.
The two types of disturbances in a power system are,
i) Large disturbance ii) Small disturbance

4. What is a small disturbance? Give example.

If the power system is operating in a steady state condition and it undergoes change, which can be properly analyzed by linearized versions of its dynamic and algebraic equations, a small disturbance is said to have occurred.

Example of small disturbance is a change in the gain of the automatic voltage regulator in the excitation system of a large generating unit.

5. What is a large disturbance? Give some examples.

A large disturbance is one for which the nonlinear equations describing the dynamics of the power system cannot be validly linearized for the purpose of analysis.

Examples of large disturbances are transmission system faults, sudden load changes, loss of generating units and line switching.

6. When is a power system said to be steady-state stable?

The power system is steady-state stable for a particular steady-state operating condition if, following a small disturbance, it returns to essentially the same steady state condition of operation.

7. When is a power system said to be transiently stable?

If the machines of the system are found to remain essentially in synchronism within the first second following a system fault or other large disturbance, the system is considered to be transiently

stable.

8. What is transient state of the power system?

The state of the system in the first second following a system fault or large disturbance is called the transient state of the power system.

9. Give the formula to calculate base current, I_b and base impedance of a three-phase system.

The equation for base current I_b is,

$$I_b = \frac{kVA_b}{\sqrt{3}\ kV_b}$$

The equation for base impedance is,

$$Z_b = \frac{kV_b\ x1000}{\sqrt{3}\, I_b}$$

Where,

I_b = Line value of base current.
kVA_b = 3-phase base KVA
kV_b = line to line base kV
Z_b = Base impedance per phase.

10. Give the equation for load impedance and load admittance per phase of a balanced star connected load.

Load impedance per phase, $Z = \frac{|V_L|^2}{P - jQ}$

Load admittance per phase, $Y = \frac{1}{Z} = \frac{P - jQ}{|V_L|^2}$

Where,

P = Three phase active power of star connected load in watts.
Q = Three phase reactive power of star connected load in VARs.
V_L = Line voltage of load.

11. Give the equation for load impedance and load admittance per phase of a balanced delta connected load.

Load impedance per phase, $Z = \frac{3|V_L|^2}{P - jQ}$

Load admittance per phase, $Y = \frac{1}{Z} = \frac{P - jQ}{3|V_L|^2}$

Where,

P = Three phase active power of delta connected load in watts.

Q = Three phase reactive power of delta connected load in VARs.

V_L = Line voltage of load.

12. What is the advantage of per unit method over percent method?

The advantage of per unit method over percent method is that 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 the result in percent.

13. Define base impedance and base kilovoltamperes. (Nov/Dec - 2008)

The base impedance is the impedance which will have a voltage drop across it equal to the base voltage when the current flowing in the impedance is equal to the base value of the current.

$$Z_b = \frac{(kV_b)^2 \, x1000}{kVA_b}$$

The base kilovoltamperes in single phase systems is the product of base voltage in kilovolts and base current in amperes.

$$kVA_b = kV_b \, x \, I_b$$

14. Define per unit value of any electrical quantity.

The per unit value of any electrical quantity is defined as the ratio of the actual value of the quantity to its base value expressed as a decimal.

$$Perunitvalue = \frac{Actual\ value}{Base\ value}$$

15. What are the quantities whose base values are required to represent the power system by reactance diagram?

The base value of voltage, current, power and impedance are required to represent the power system by reactance diagram. Selection of base values for any two of them determines the base values of the remaining two. Usually the base values of voltage and power are chosen in kilovolt and KVA or MVA respectively. The base values of current and impedance are calculated using the chosen bases.

16. What is the need for base values?

The components of 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 power system components are expressed with reference to a common value called base value. Then all the voltages, power, current and impedance ratings of the components are expressed as a percent or per unit of the base value.

17. Write the equation for converting the per unit impedance expressed in one base to another.

$$Z_{p.u,new} = Z_{p.u,old} \, x \left(\frac{kV_{b,old}}{kV_{b,new}} \right)^2 x \left(\frac{MVA_{b,new}}{MVA_{b,old}} \right)$$

18. List the advantages of per unit computations.

1. The per unit impedance referred to either side of a single phase transformer is the same.
2. The per unit impedance referred to either side of a three phase transformer is the same regardless of the three phase connections whether they are Y-Y, Δ-Δ or Δ-Y

3. The chance of confusion between the line and phase quantities in a three phase balanced system is greatly reduced.
4. The manufacturers usually provide the impedance values in per unit.
5. The computational effort in power system is very much reduced with the use of per unit quantities.

19. Give the equation for transforming base kV on LV side to HV side of a transformer and vice versa.

$$\text{Base kV on HV side} = \text{Base kV on LV side} \ \text{x} \frac{\text{HV rating}}{\text{LV rating}}$$

$$\text{Base kV on LV side} = \text{Base kV on HV side} \ \text{x} \frac{\text{LV rating}}{\text{HV rating}}$$

20. Give the equation for base current and base impedance of a balanced three phase circuit.

$$Base\ current, A = \frac{base\ kVA\ 3\phi}{\sqrt{3}\ x\ base\ voltage, kV_{LL}}$$

$$Base\ impedance = \frac{(base\ voltage, kV_{LL})^2}{base\ MVA_{3\phi}}$$

21. Why the line value of voltage directly used for per unit calculation in three phase systems?

The per unit value of a line-to-neutral (V_{LN}) on the line-to-neutral voltage base ($V_{b,LN}$) is equal to the per unit value of the line-to-line voltage (V_{LL}) at the same point on the line-to-line voltage base ($V_{b,LL}$) if the system is balanced.

$$i.e., \frac{V_{LN}}{V_{b,LN}} = \frac{V_{LL}}{V_{b,LL}}$$

22. Why the three phase kVA directly used for per unit calculation in three phase systems?

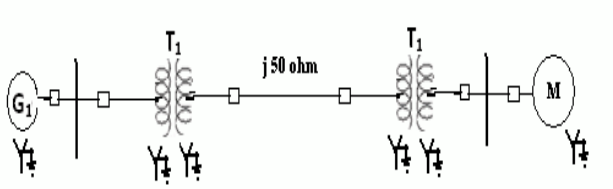
The per unit value of a 3-phase kVA on the 3-phase kVA base is identical to the per unit value of kVA per phase on the kVA per phase base.

$$i.e., \frac{3-phase\ kVA}{3-phase\ base\ kVA} = \frac{kVA\ per\ phase}{Base\ kVA\ per\ phase}$$

Therefore in 3 phase systems, the line value of voltage and 3 phase kVA are directly used for per unit calculations.

Part B (16 Mark Questions)

1. What is the need for system analysis in planning and operation of power system?Explain.
2. Explain the advantages of the p.u form of representation?
3. Define the per unit value of a quantity. How will you change the base impedance fromone set of base values to another set?
4. Explain the steady state and transient state with the help of a RL circuit.
5. Examine the reactance diagram for the power system shown in fig. Neglect resistance and use a base of 100MVA, 220kV in 50KΩ line. The ratings of the generator motor and transformer are give below.



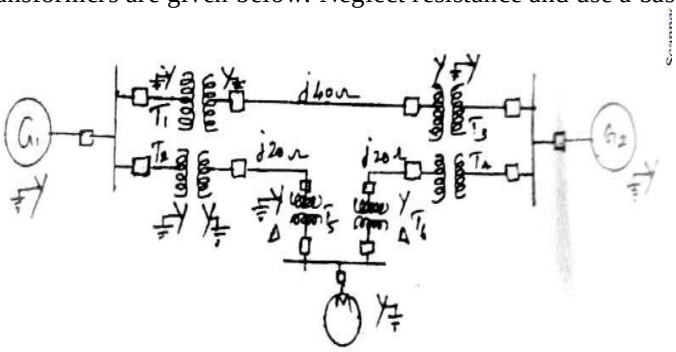
Generator: 40MVA, 25KV, X'' =20%.Synchronous Motor: 50MVA, 11KV, X'' =30% T1: Y-Y transformer : 40MVA 33/220KV, X=15%T2:Y- Y transformer : 30 MVA 11/220KV, X=15%

6. What are the advantages of using per unit system?
7. The parameters of a four system are as under:

Line No.	Line starting bus	Line ending bus	Line impedance(pu)	Line Charging Admittance(pu)
1	1	2	0.2+j0.8	j0.02
2	2	3	0.3+j0.9	j0.03
3	2	4	0.25+j1.0	j0.04
4	3	4	0.2+j0.8	j0.02
5	1	3	0.1+j0.4	j0.01

Point out the Network and find bus admittance matrix.

8. Draw the reactance diagram for the power system shown in figure. The ratings of generator, motor and transformers are given below. Neglect resistance and use a base of 50MVA, 13.8kV in the 40 ohmline



Generator G1: 20MVA,18kV, X"=20% Generator G2: 40MVA 18kV,X"=20%
Synchronous motor:30MVA,13.8kV,X"=20%
3phase Y-Y Transformer:20MVA 13.8/20kV, X=10%
3 phase Y-Y Transformer:15MVA,138/13.8kV,X=10%

9. With neat diagrams, explain the transformer model used for per phase analysis.
10. Discuss in detail about the modeling of transmission lines.
11. Clearly explain the basic components of a power system.

UNIT-II POWER FLOW ANALYSIS

Part A (2 marks for each question)

1. Write the most important mode of operation of power system and mention the major problems encountered with it.

Symmetrical steady state is the most important mode of operation of power system. Three major problems are encountered in this mode of operation. They are,

Load flow problem

1) Optimal load scheduling problem
2) Systems control problem

2. Why power flow analysis is made?

Power flow analysis is performed to calculate the magnitude and phase angle of voltages at the buses and also the active power and reactive voltamperes flow for the given terminal or bus conditions. The variables associated with each bus or node is,

a. Magnitude of voltage |V|
b. Phase angle of voltage δ
c. Active power, P
d. Reactive voltamperes, Q

3. What is power flow study or load flow study?

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

4. What are the information that are obtained from a load flow study?

The information obtained from a load flow study are magnitude and phase angles of bus voltages, real and reactive power flowing in each line and line losses. The load flow solution also gives the initial conditions of the system when the transient behavior of the system is to be studied.

5. What is the need for load flow study?

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.

6. What are the works involved in a load flow study?

The following has to be performed for a load flow study.

a. Representation of the system by single line diagram.
b. Formation of impedance diagram using the information in single line diagram.
c. Formulation of network equations
d. Solution of network equations.

7. What are the different types of buses in a power system?

The buses of a power system can be classified into three types based on the quantities being specified for the buses, which are as follows:

a. Load bus or PQ bus (P and Q are specified)
b. Generator bus or voltage controlled bus or PV bus (P and V are specified)
c. Slack bus or swing bus or reference bus (|V| and δ are specified)

8. Define voltage controlled bus (generator bus/PV bus).

A bus is called voltage controlled bus if the magnitude of voltage |V| and real power (P) are specified for it. In a voltage controlled bus, the magnitude of the voltage is not allowed to change. Voltage controlled bus is also called as Generator bus and PV bus.

9. What is PQ bus (load bus)?

A bus is called PQ bus or load bus when real and reactive components of power are specified for the bus. In a load bus, the voltage is allowed to vary within permissible limits.

10. What is swing bus (slack bus/reference bus)?

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 for the line losses. Usually one of the generator bus is selected as the swing bus.

11. What is the need for slack bus?

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 the 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 line flow equations.

12. List the quantities specified and the quantities to be determined from load flow study for various types of buses.

The following table shows the quantities specified and the quantities to be obtained for various types of buses.

BUS	**Quantities specified**	**Quantities to be obtained**
Load Bus	P,Q	|V|, δ
Generator Bus	P, |V|	Q, δ
Slack Bus	|V|, δ	P, Q

13. Write the load flow equation of Gauss and Gauss-Seidel method.

The load flow equation of Gauss method is given by,

$$V_p^{K+1} = \frac{1}{Y_{pp}}\left[\frac{P_p - jQ_p}{\left(V_p^K\right)^*} - \sum_{\substack{q=1 \\ q\neq p}}^{n} Y_{pq}V_q^K\right]$$

The load flow equation of Gauss-Seidel method is given by,

$$V_p^{K+1} = \frac{1}{Y_{pp}}\left[\frac{P_p - jQ_p}{\left(V_p^K\right)^*} - \sum_{q=1}^{p-1} Y_{pq}V_q^K - \sum_{q=p+1}^{n} Y_{pq}V_q^K\right]$$

V_p^{K+1} and V_p^K= (K+1) and Kth iteration voltage of bus 'p' respectively.
V_q^{K+1} and V_q^K = (K+1) and Kth iteration voltage of bus 'q' respectively.

14. Write the load flow equation of Newton-Raphson method.

The load flow equation of Newton Raphson method is given by,

$$P_p = \sum_{q=1}^{n}\left[e_p(e_qG_{pq} + f_pB_{pq}) + f_p(f_qG_{pq} - e_pB_{pq})\right]$$

$$Q_p = \sum_{q=1}^{n}\left[f_p(e_qG_{pq} + f_pB_{pq}) - e_p(f_qG_{pq} - e_pB_{pq})\right]$$

$$\left|V_p\right|^2 = e_p^2 + f_p^2$$

15. Discuss the effect of acceleration factor in the load flow solution algorithm.

In load flow solution by iterative methods, the number of iterations can be reduced if the

correction voltage at each bus is multiplied by some constant. The multiplication of the constant will increase the amount of correction to bring the voltage closer to the value it is approaching. The multipliers that accomplish this improved converged are called acceleration factors. An acceleration factor of 1.6 is normally used in load flow problems.

16. How will you account for voltage controlled buses in the load flow algorithm?

The acceleration factor is a real quantity and it modifies the magnitude of bus voltage alone. Since in voltage controlled bus, the magnitude of bus voltage is not allowed to change, the acceleration factor is not used for voltage controlled bus.

17. What do you mean by a flat voltage start?

In iterative methods of load flow solution, the initial voltage of all buses except slack bus is assumed as 1+j0 p.u. This is referred to as flat voltage start.

18. When the generator bus is treated as load bus? What will be the reactive power and bus voltage when the generator bus is treated as load bus?

If the reactive power of a generator bus violates the specified limits, then the generator bus is treated as 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.

19. How approximation is performed in Newton-Raphson method?

In Newton-Raphson method, the set of non-linear simultaneous (load flow) equations are approximated to a set of linear simultaneous equations using Taylor's series expansion and the terms are limited to first order approximation.

20. What are the advantages of Gauss-Seidel method?

The advantages of Gauss-Seidel method are,
- **a.** Calculations are simple and so the programming task is less
- **b.** The memory requirement is less
- **c.** Useful for small systems.

21. What are the disadvantages of Gauss-Seidel method?

The disadvantages of Gauss-Seidel method are,
- **a.** Requires large number of iterations to reach convergence.
- **b.** Not suitable for large systems.
- **c.** Convergence time increases with size of the system.

22. What is Jacobian matrix? How the elements of Jacobian matrix are computed?

The matrix formed from the derivates of load flow equations is called Jacobian matrix and it is denoted by J.

The elements of Jacobian matrix will change in every iteration. In each iteration, the elements of the Jacobian matrix are obtained by partially differentiating the load flow equations with respect o unknown variable and then evaluating the first derivates using the solution of previous iteration.

23. What are the advantages of Newton-Raphson method?

The advantages of Newton-Raphson method are,
- **a.** This load flow method is faster, more reliable and he results are accurate.
- **b.** Requires less number of iterations for convergence.
- **c.** The number of iterations are independent of the size of the system.
- **d.** Suitable for large system.

24. What are the disadvantages of Newton-Raphson method?

The disadvantages of Newton-Raphson method are,
- **a.** Programming is more complex.

b. The memory requirement is more.
c. Computational time per iteration is higher due to larger number of calculations per iteration.

25. Mention (any) three advantages of N-R method over G-S method?

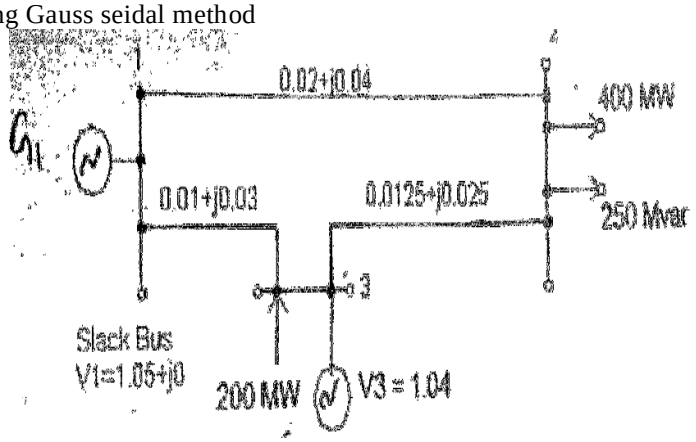
The three advantages of N-R method over G-S method are,
a. The N-R method has quadratic convergence characteristics and so converges faster than G-S method.
b. The number of iterations for convergence is independent of the system in N-R method.
c. In N-R method, the convergence is not affected by the choice of slack bus.

Part B (16 Mark Questions)

1. With the help of a neat flow chart, explain the Newton-Raphson method of load flow solution when the system contains voltage controlled busses in addition to swing bus and load bus.
2. For the sample system shown in the fig. the generators are connected at all four buses while the loads are at buses 2 and 3. Assuming a flat voltage start, examine bus voltages and bus angles at the end of first Gauss seidal iterations and consider the reactive power limits as $0.2 \leq Q2 \leq 1$.

Bus	P in pu	Q in pu	V in pu	Remarks
1	-	-	$1.04 \angle 0^{o}$	Slack bus
2	0.5	-	1.04pu	PV bus
3	-1.0	0.5	-	PQ bus
4	0.3	-0.1	-	PQ bus

3. The Figure shows the one line diagram of a simple 3 bus system with generation at buses 1 and 3 . Line impedance are marked in p.u on a 100 MVA base. Determine the bus voltages at the end of second iteration using Gauss seidal method



4. The system data for a load flow problem are given in table.
(i) Compute Y bus.
(ii) Solve bus voltages at the end of first iteration by G-S method by taking $\alpha = 1.6$.

Line no	Bus code	Admittance in pu
1	1-2	2-j8
2	1-3	1-j4
3	2-3	0.6-j2.6

5. Compare Gauss-Seidel method and Newton-Raphson method of load flow studies
6. Explain clearly with detailed flowchart, the computational procedure for load flow solution using N-R method when the system contains all types of buses.
7. Explain the step by step computational procedure for the Newton-Raphson method of load flow studies.

8. Explain bus classification in power flow analysis with their known and unknown quantities.

9. Derive the static load flow equations of n-Bus system.
10. Explain the step by step computational procedure for the Gauss-Seidel method of loadflow studies

UNIT-III SYMMETRICAL FAULT ANALYSIS

Part A (2 marks for each question)

1. What is the need for short circuit studies or fault analysis?

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 of these devices mainly depends on various currents that may flow in the fault conditions.

2. What is the reason for transients during short circuits?

The faults 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, so the faults are associated with transients.

3. What is meant by a fault?

A fault in a circuit is any failure which interrupts 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 equipments, if it is allowed to persist for a long time. Hence every part of a system has been protected by means of relays and circuit breakers to sense the faults and to isolate the faulty part from the healthy part ofthe network in the event of fault

4. Why faults occur in a power system?

Faults occur in a power system due to insulation failure of equipments, flashover of lines initiated by a lightening stroke, permanent damage to conductors and towers or accidental faulty operations.

5. How are the faults classified?

In one method, the faults are classified as,

1. Shunt faults - due to short circuits in conductors
2. Series faults - due to open conductors.In

another method,

1. Symmetrical faults - fault currents are equal in all the phases and can beanalyzed on per phase basis
2. Unsymmetrical faults – fault currents are unbalanced and so they can beanalyzed only using symmetrical components.

6. List the various types of shunt and series faults.

Various types of shunt faults are

1. Single line-to-ground fault
2. Line-to-line fault

3. Double line-to-ground fault
4. Three phase fault Various

Types of series faults are,

1. One open conductor fault
2. Two open conductor fault

7. What is meant by symmetrical fault?

The fault is called symmetrical fault if the fault current is equal in all the phases. This fault conditions are analyzed on per phase basis using Thevenin's theorem or using bus impedance matrix. The three-phase fault is the only symmetrical fault.

8. List out the differences in representing the power system for load flow and shortcircuit studies.

Load flow studies	Fault analysis
1. Both resistances and reactances are Considered. 2. Bus admittance matrix is useful. 3. The exact voltages and currents are to be determined.	Resistances are neglected. Bus impedance matrix is used. The voltages can be safely assumed as 1 p.u. and the prefault current can be neglected.

9. For a fault at a given location, rank the various faults in the order ofseverity.

In a power system, the most severe fault is three phase fault and less severe faultis open conductor fault. The various faults in the order of decreasing severity are,

1) 3 phase fault
2) Double line-to-ground fault
3) Line-to-line fault
4) Single line-to-ground fault
5) Open conductor fault

10. What is meant by fault calculations?

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

11. What are the assumptions made in short circuit studies of a large power systemnetwork?

1) The phase to neutral emfs of all generators remain constant, balanced and unaffectedby the faults.
2) Each generator is represented by an emf behind either the subtransient or transient reactance depending upon whether the short circuit current is to be found immediatelyafter the short circuit or after about 3 – 4 cycles.
3) Load currents may often be neglected in comparison with faultcurrents.
4) All network impedances are purely reactive. Thus the series resistances of lines andtransformers are neglected in comparison with their resistances.
5) Shunt capacitances and shunt branches of transformers are neglected. Hence, transformer reactances are taken as their leakage reactances.

12. What is synchronous reactance?

The synchronous reactance is the ratio of induced emf and the steady state rms current (i.e., it is the reactance of a synchronous machine under steady state condition). It is the sum of leakage reactance and the

reactance representing armature reaction. It is given by,

$X_s = X_l + X_a$

Where,

X_s = Synchronous reactance X_l = Leakage reactance

X_a = Armature reaction reactance.

13. How symmetrical faults are analyzed?

The symmetrical faults are analyzed using per unit reactance diagram of the power system. Once the reactance diagram is formed, then the fault is simulated by short circuit or by connecting the fault impedance at the fault point. The currentsand voltages at various parts of the system can be estimated by any of the following methods.

1) Using Kirchoff's laws
2) Using Thevenin's theorem
3) By forming bus impedance matrix.

14. Define doubling effect and DC off-set current. Doubling effect:

If a symmetrical fault occurs when the voltage wave is going through zero then the maximum momentary short circuit current will be double the value of maximum symmetrical short circuit current. This effect is called doubling effect.

DC off-set current:

The unidirectional transient component of short circuit current is called DC off- set current.

15. Differentiate between subtransient and transient reactance.

Subtransient reactance	Transient reactance
1) This is the ratio of induced emf and subtransient current. 2) Flux created by induced currents in thedamper winding is included. 3) This is the smallest reactance among the reactance values. 4) This cannot be extrapolated.	1) This is the ratio of induced emf and transient current. 2) There is no damper winding and henceno flux is created. 3) This is larger than the subtransientreactance. 4) This can be extrapolated backwards intime

Part B (16 Mark Questions)

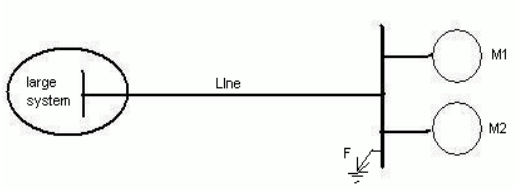
1. A 3 phases 5 MVA, 6.6 kV alternator with a reactance of 8% is connected to a feeder series impedance (0.12+j0.48) ohm/phase/km through a step up transformer. The transformer rated at 3 MVA, 6.6 kV/33kV and has reactance of 5%.Determine the fault current supplied by the generator operating under no load with a voltage of 6.9 kV, when a 3 phases symmetrical fault occurs at a point 15km along the feeder.

2. Two synchronous motor are connected to the bus of large system through a short transmission line shownin fig. The rating of the various components is given.

MOTOR (each): 1 MVA, 440V, 0.1 p.u.

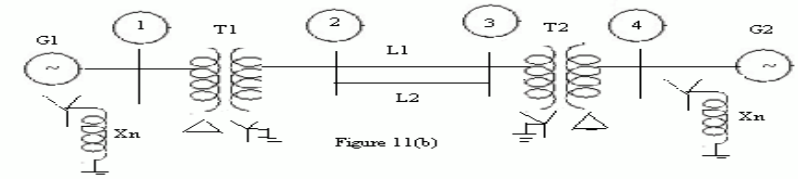
Transient reactance line: 0.05Ω (reactance)

Large system: Short circuit MVA at its bus at 440V is 8 When the motor are operating at 400V, examine the short circuit current (symmetrical) fed into a three phase fault at motor bus.

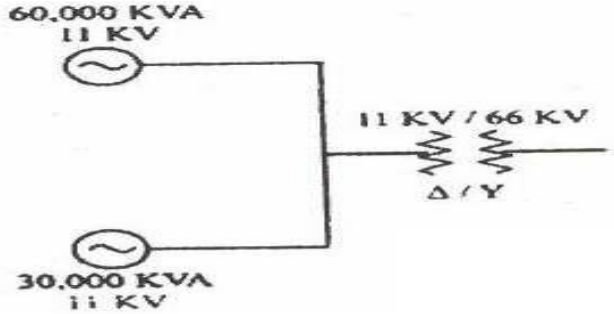


3. Explain the step by step procedure to find the fault current of three phase symmetrical fault by using thevenin's theorem.

4. A symmetrical fault occurs on bus 4 of system shown in figure; examine the fault current, post fault voltages, line flows.
Generator G_1 ,G_2 :100MVA,20KV,X_1=15%.
Transformer T_1, T_2:, X_{leak}=9%, Transmission line L_1,L_2: X_1=10%



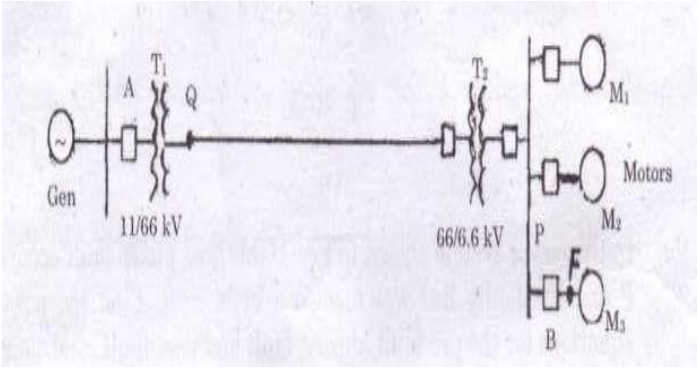
5. Examine the bus impedance matrix using bus building algorithm forthe given network.
6. A 3-phase 5MVA, 6.6 KV alternators with a reactance of 8% is connected to a feeder of series impedance (0.12+j0.48) ohm/phase/Km through a step up transformer. The transformer is rated at 3 MVA, 6.6 KV/33KV and has a reactance of 5%. Calculate the fault current supplied by the generator operating under no load with a voltage of 6.9 KV when a three phase symmetrical fault occurs at a point 15Km along the feeder.
7. Two generator are connected in parallel to the low voltage side of a 3Φ delta star transformer as shown in figure. generator 1 is rated 60,000 KVA, 11 KV.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 11 KV- delta/66KV star with a reactance of 10%.before a fault occurred, the voltage on the HT side of the transformer is 63KV.the transformer is unloaded and there is no circulating current between the generators. Calculate the sub transient current in eachgenerator when a three phase fault occurs on the HT side of the transformer.



8. A generator transformer unit is connected to a line circuit breaker.the unit rating are:
Generator: 10MVA, 6.6KV; Xd"=0.1 p.u, Xd'=0.2 p.u and Xd=0.8 p.u
Transformer:10mva,6.9/33KV,X=0.08 p.u,
The system is operating on no load at a line voltage of 30 KV, when a 3Φ fault occurs on the line jest beyond the circuit breaker.
Solve
(i) The initial symmetrical rms current in the breaker.
(ii) The maximum possible dc offset current in the breaker. (iii)the momentary current rating of the breaker
(iv) the current to be interrupted by the breaker and the interrupting KVA
(v) the sustained short circuit current in the breaker.

9. A 25MVA,11kV generator with Xd"=20% is connected through a transformer, line and transformer to a bus that supplies three identical motors as shown in figure. Each motor has Xd"=20% and Xd'=30% on a base of 5 MVA,6.6kV.The three phase rating of the step-up transformer is 25MVA,11/66kV with a leakage reactance of 10% and that of the step-down transformer is 25MVA,66/6.6kV with a leakage

reactance of 10%.. The bus voltage at the motors is 6.6kV when a three phase fault occurs at the point F, For the specified fault, calculate (i) the sub transient current in the fault (ii) the sub transient current in the Breaker B.(iii) the momentary current in breaker B and (iv) the current to be interrupted by breaker B in five cycles



10 (i)Write a short note on fault current in synchronous machine
(ii)What are the assumptions made in fault analysis

UNIT-IV UNSYMMETRICAL FAULT ANALYSIS

Part A (2 marks for each question)

1. What are symmetrical components?

An unbalanced system of N related vectors can be resolved into N systems ofbalanced vectors called symmetrical components. Positive sequence components Negative sequence components Zero sequence components.

2. Write the symmetrical components of three phase system.

In a 3-phase system, the three unbalanced vectors (either current or voltagevectors) can be resolved into three balanced system of vectors. They are,

1) Positive sequence components
2) Negative sequence components
3) Zero sequence components.

3. Define negative sequence and zero sequence components.

Negative sequence components consist of three phasors equal in magnitude, displaced from each other by 120° in phase, and having the phase sequence opposite to that of the original phasors. V_{a2}, V_{b2} and V_{c2} are the negative sequence components of V_a, V_b and v_c.

Zero sequence components consist of three phasors equal in magnitude and with zero phase displacement from each other. V_{ao}, V_{bo} and V_{co} are the zero sequence components of V_a, V_b and V_c.

4. Express the unbalanced voltages V_a, V_b and V_c in terms of symmetrical components V_{a1}, V_{a2} and V_{a0}.

The expressions of unbalanced voltages in terms of symmetrical components are,

$$V_a = V_{ao} + V_{a1} + V_{a2}$$

$$V_b = V_{ao} + a^2 V_{a1} + aV_{a2}$$

$$V_c = V_{ao} + aV_{a1} + a^2 V_{a2}$$

(Or)

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

5. Express the symmetrical components V_{a1}, V_{a2} and V_{a0} in terms of unbalanced vectors V_a, V_b and V_c.

The expressions of symmetrical components in terms of unbalanced vectors are,

$$V_{ao} = \frac{1}{3}(V_a + V_b + V_c)$$

$$V_{a1} = \frac{1}{3}(V_a + aV_b + a^2V_c)$$

$$V_{a2} = \frac{1}{3}(V_a + a^2V_b + aV_c)$$

(Or)

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

6. Define the operator 'a' and express the value of 'a' and 'a²' in both polar andrectangular form.

An operator which causes a rotation of 120° in the anticlockwise direction isknown as operator 'a'. The value of 'a' is $1\angle 120^o$.

The polar form and rectangular form of operator 'a' is given by,$a = 1\angle 120^o$
polar form
$= -0.5 + j0.806$ ---------- rectangular form

The polar form and rectangular form of operator 'a^2' is given by,$a^2 = 1\angle 240^o$
polar form
$= -0.5 - j0.806$ ---------- rectangular form

7. what are sequence impedances and sequence networks?

The sequence impedances are the impedances offered by the devices orcomponents for the like sequence component of the current.

The single phase equivalent circuit of a power system consisting of impedances tocurrent of any one sequence only is called sequence network.

8. What assumption is made at the star / delta transformer?

It is that the positive sequence quantities on the HV side lead their corresponding positive sequence quantities on the LV side by 30°. The reverse is the case for negative sequence quantities wherein HV quantities lag the corresponding LV quantities by 30°.

9. What is an unsymmetrical fault? List the various unsymmetrical faults.

The fault is called unsymmetrical fault if the fault current is not equal in all thephases. The unsymmetrical faults in a power system are,

1) Single line-to-ground fault.
2) Line-to-line fault.
3) Double line-to-ground fault
4) Open conductor fault.

10. Define positive sequence and negative sequence impedances.

The positive sequence impedance of an equipment is the impedance offered bythe equipment to the flow of positive sequence current.

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

11. Write the symmetrical components of three phase system.

In a 3-phase system, the three unbalanced vectors (either current or voltage vectors) can be resolved into three balanced system of vectors. They are,

4) Positive sequence components
5) Negative sequence components
6) Zero sequence components.

12. What are symmetrical components?

An unbalanced system of N related vectors can be resolved into N systems of balanced vectors called symmetrical components. Positive sequence components Negative sequence component Zero sequence components.

Part B (16 Mark Questions)

1. Examine the sequence impedance of synchronous machine, transmission lines and Star connected loads.
2. Label the transformer zero sequence equivalent circuits for thevarious winding connections and delta connected load
3. A 25MVA, 11KV, three phase 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 one line diagram a of figure. The motors have rated inputs of 15 and

7.5 MVA both 10KV with 25% sub transient reactance. The three phase transformers are rated 30MVA, 10.8/121KV, and connection delta-star with leakage reactance of 10% each. The series reactance of the line is 100 ohms. Label the positive and negative sequence networks of the system with reactance marked in per unit.

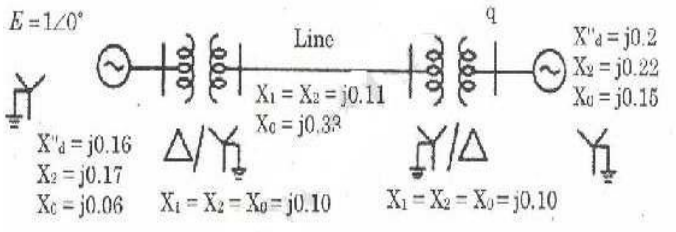
4. Examine the sequence network for a double line to ground (LLG)fault.
5. A salient pole generator without dampers is rated 20 MVA, 13.6 KV and has direct axis sub – transient reactance of 0.2 per unit. The negative and zero sequence reactance's are, respectively,

0.35 and 0.1 per unit. The neutral of the generator is solidly grounded. With the generator operating unloaded at rated voltage with $E_{an}=1.0 \angle 0°$ per unit, a single line to ground fault occurs at the machine terminals, which then have per -unit voltage to ground,

$V_a = 0$; $V_b = 1.013 \angle -102.25°$; $V_c = 1.013 \angle 102.25°$

Give the sub transient current in the generator and the line to linevoltage for sub transient conditions due to the fault.

6. Show the expression for fault current in double line to ground fault on unloaded generator. Draw an equivalent network showing the inter connection of networks to simulate double line to ground fault
7. A 25 MVA,13.2KV alternator with solidly grounded neutral has a sub transient reactance os 0.25.the negative and zero sequence reactance are 0.35 and 0.01 p.u .respectively if a double line to ground fault occuers at the terminals of the alternator. Point out the fault current and line to line voltage at the fault.
8. Point out the expression for fault current for a line to line fault taken place through impedance Zb in a power system.
9. A Double Line to Ground fault occurs on line b and c at point F in the system of figure . Point out the sub transient current in phase c of the machine 1.assuming pre fault current to be zero. Both machine are rated 1200 KVA,600 V with reactance of X''=X2=10% AND XO=5%.each tree phase transformer is rated 1200KVA,600V- delta/300V-star with leakage reactance of 5%.the reactance of the transmission line are X1=X2=20% and X0=40% on the base of 1200 KVA,3300V.the reactance of the neutral of the grounding reactors are 5% on the KVA base of the machines.
10. Calculate the sub transient current in each phase for a dead short circuit on the one phase to ground at bus 'q' for the system shown in figure below.



UNIT V STABILITY ANALYSIS

Part A (2 marks for each question)

1. Define Stability.

The stability of a system is defined as the ability of power system to return to a stable operation in which various synchronous machines of the system remain in synchronism or 'in step' with each other, when it is subjected to a disturbance.

2. Define steady state stability.

The steady state stability is defined as the ability of a power system to remain stable i.e., without loosing synchronism for small disturbances.

3. Define transient stability.

The transient stability is defined as the ability of a power system to remain stable i.e., without loosing synchronism for large disturbances.

4. Write any three assumptions upon transient stability.

a. Rotor speed is assumed to be synchronous. In fact, it varies insignificantlyduring the course of the stability study.
b. Shunt capacitances are not difficult to account for in a stability study.
c. Loads are modeled as constant admittances.

5. What is meant by steady state stability limit?

When the load on the system is increased gradually,maximum power that can be transmitted without losing synchronism is termed as steady state stability limit. In steady state, the power transferred by synchronous machine of a power system is always less than the steady state stability limit.

6. What is transient stability limit?

When the load on the system is increased suddenly, maximum power that can betransmitted without losing synchronism is termed as transient state stability limit.

Normally, steady state stability limit is greater than transient state stability limit.

7. How to improve the transient stability limit of power system?

a. Increase of system voltages
b. Use of high speed excitation systems.
c. Reduction in system transfer reactance
d. Use of high speed reclosing breakers.

8. What is stability study?

The procedure of determining the stability of a system upon occurrence of a disturbance followed by various switching off and switching on actions is called stability study.

9. How do you classify steady state stability limit. Define them.

Depending on the nature of the disturbance, the steady state stability limit is classified into,

a. Static stability limit refers to steady state stability limit that prevails without the aid of regulating devices.
b. Dynamic stability limit refers to steady state stability limit prevailing in an unstable system with the help of regulating devices such as speed governors, voltage regulators, etc.

10. What are the machine problems seen in the stability study.

1. Those having one machine of finite inertia machines swinging with respect toan infinite bus
2. Those having two finite inertia machines swinging with respect to each other.

11. What are the assumptions made in solving swing equation?

1) Mechanical power input to the machine remains constant during the period of electromechanical transient of interest.
2) Rotor speed changes are insignificant that had already been ignored informulating the swing equations.
3) Effect of voltage regulating loop during the transient are ignored.

12. Define swing curve. What is the use of swing curve?

The swing curve is the plot or graph between the power angle δ, and time, t.

It is usually plotted for a transient state to study the nature of variation in δ fora sudden large disturbance. From the nature of variations of δ, the stability of a system for any disturbance can be determined.

13. Give the control schemes included in stability control techniques?

The control schemes included in the stability control techniques are:

a. Excitation systems
b.Turbine valve control
c.Single pole operation of circuit breakersd.Faster fault clearing times

14. What are the systems design strategies aimed at lowering system reactance?

The system design strategies aimed at lowering system reactance are:

a. Minimum transformer reactance b.Series capacitor compensation of linesc.Additional transmission lines.

15. What are coherent machines?

Machines which swing together are called coherent machines. When both ωs and δare expressed in electrical degrees or radians, the swing equations for coherent machines can be combined together even though the rated speeds are different. This is used in stability studies involving many machines.

16. State equal area criterion.

In a two machine system under the usual assumptions of constant input , no dampingand constant voltage being transient reactance , the angle between the machines either increases or else, after all disturbances have occurred oscillates with constant amplitude. There is a simple graphical method of determining whether the system comes to rest withrespect to each other. This is known as equal area criterion

17. What are various faults that increase severity of equal area criterion?

The various faults that increases severity of equal area criterion are,A Single line to ground fault
A Line to line fault
A Double line to ground faultA
Three phase fault

18. List the types of disturbances that may occur in a single machine infinite bus bar system of the equal area criterion stability

The types of disturbances that may occur are,Sudden change in mechanical input Effect of clearing time on stability Sudden loss of one of parallel lines
Sudden short circuit on one of parallel lines

i) Short circuit at one end of line
ii) Short circuit away from line ends
iii) Reclosure

19. Define critical clearing angle

The critical clearing angle δcc is the maximum allowable change in the power angle δ before clearing the fault , without loss of synchronism.

20. Define critical clearing time.

The critical clearing time , tcc can be defined as the maximum time delay that can be allowed to clear a fault without loss of synchronism . The time corresponding tothe critical clearing angle is called critical clearing time tcc.

21. What are the assumptions that are made inorder to simplify the computational task in stability studies?

The assumptions are,

- The D.C offset currents and harmonic components are neglected. Thecurrents and voltages are assumed to have fundamental component alone.
- The symmetrical components are used for the representation ofunbalanced faults.
- It is assumed that the machine speed variations will not affect thegenerated voltage.

22. What is Multimachine stability?

If a system has any number of machines, then each machine is listed for stability byadvancing the angular position, δ of its internal voltage and noting whether the electric power output of the machine increases (or) decreases. If it increases,
i.e if $\partial Pn / \partial \delta n > 0$
then machine n is stable. If every machine is stable, then the system having any number of machine is stable.

23. What is meant by an infinite bus?

The connection or disconnection of a single small machine on a large system wouldnot affect the magnitude and phase of the voltage and frequency. Such a system of constant voltage and constant frequency regardless of the load is called infinite bus bar system or infinite bus.

24. List the assumptions made in multimachine stability studies.
The assumptions made are,

- The mechanical power input to each machine remains constant during the entire period of the swing curve computation
- Damping power is negligible

- Each machine may be represented by a constant transient reactance inseries with a constant transient voltage.
- The mechanical rotor angle of each machine coincides with δ ,the electrical phase angle of the transient internal voltage.

25. Explain the concept synchronous speed.

The mechanical torque Tm and the electrical torque Te are considered positive for synchronous generator. Tm is the resultant shaft torque which tends to accelerate the rotor in the positive θm direction of rotation . Under steady-state operation of the generator Tm and Te are equal and the accelerating torque Ta is zero. Hence there is noacceleration of deceleration of the rotor, masses and the resultant constant speed is the synchronous speed.

Part B (16 Mark Questions)

1. Derive the swing equation for a single machine connected to infinite bus system. Statethe assumptions if any and state the usefulness of this equation. Neglect the damping.
2. Discuss the various factors affecting the transient stability of the system.
3. With the help of a neat flowchart, explain the modified Euler method of solving theswing equations.
4. State the bad effects of instability. Distinguish between steady state and transientstability.
5. Write short notes on assumptions made in deducing equal area criterion.
6. State and explain equal area criterion. How do you apply equal area criterion to findthe maximum additional load.
7. Describe the equal area criterion for transient stability analysis of a system.
8. Mention the assumptions clearly and developing necessary equations, describe the stepby step solution of swing bus.
9. Derive the swing equation of a synchronous machine swinging against an infinite bus.Clearly state the assumptions in deducing the swing equation.
10. Derive the swing equation for a synchronous machine.
11. Explain critical clearing time and critical clearing angle, deriving the expressions.
12. Explain the solution of swing equation by Runge Kutta Method..