Sri Vidya College of Engineering And Technology
Virudhunagar – 626 005
Department of Electrical and Electronics Engineering

## SHORT QUESTIONS AND ANSWERS

Year/ Semester/ Class : III/ V/ EEE Academic Year: 2017-2018
Subject Code/ Name: EE6501/ Power System Analysis

## UNIT – I INTRODUCTION

**1. What is the need for system analysis in planning and operation of power system?**

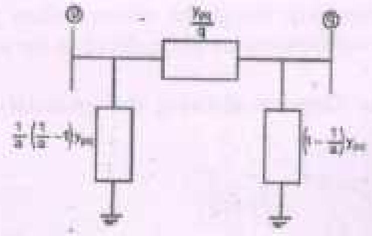
The successful operation of a power system depends largely on the engineer's ability to provide reliable, uninterrupted and quality service to loads. The systems being planned are to be optimal with respect to cost, performance and operating efficiency. For this, better planning tools are required. The major power system tools are :

1. Load flow analysis
2. Short circuit analysis or fault calculations
3. Stability analysis
4. System protection and relay coordination.

**2. How are the base values chosen in per unit representation of a power system?**

- **Selection of Base MVA:** First a base MVA is Chosen. The same MVA will be used in all parts of the system. It may be the largest MVA of a section , or total MVA of the system or any value like 10,100,1000 MVA etc.
- **Selection of Base KV:** The rated voltage of the largest section may be taken as base KV. The base voltages of remaining section are assigned depends on the turns ratio of the transformers

**3. π circuit representation of a transformer with off-nominal tap ratio 'a':**



**4. Define per unit value. Write the equation for base impedance with respect to three phase system.**

The per unit value of any quantity is defined as the ratio of the actual value of the quantity to the base value expressed as a decimal. The base value is an arbitrary chosen value of the quantity.

Per unit value = Actual value / Base value

Base impedance / phase, $Z_b = (kV_b)^2 / MVA_b$

**5. List the two advantages of per-unit Computation.**

(i) Manufacturers 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 have a very large range.

(iii)The p.u. impedance of circuit element connected by transformers expressed on a proper base will be same if it is referred to either side of a transformer.

(iv) The p.u. impedance of a three phase transformer is independent of the type of winding connection.

**6. Write the equation for converting the p.u. impedance expressed in one base to another base.**

$$Z_{pu,new} = Z_{pu,old} \times (kV_{b,old} / kV_{b,new})^2 \times (MVA_{b,new} / MVA_{b,old})$$

**7. What are the components of power system?**

The components of power system are

- Generators
- Power transformers
- Transmission lines
- Substation transformers
- Distribution transformers
- Loads

**8. What is the need for base values?**

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 or per unit of the base value.

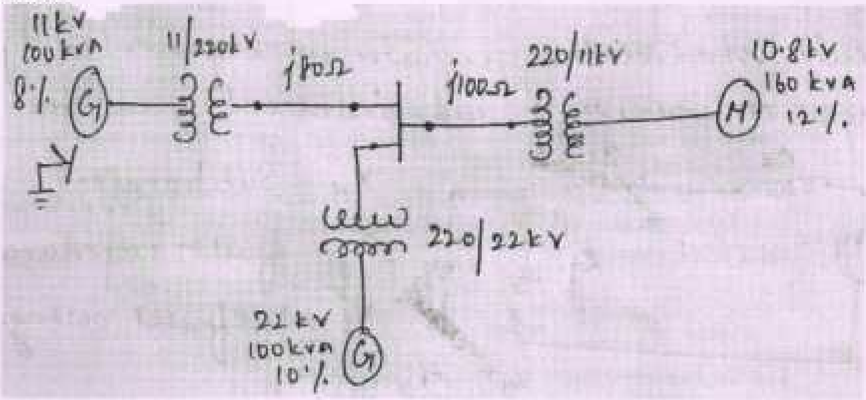
**9. What is bus admittance matrix?**

The matrix consisting of the self and mutual admittances of the network of a power system is called bus admittance matrix.

**10. What is single line diagram? Give it advantages.**

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

**11. Draw the single line diagram showing the essential parts in the power system network.**



**12. What is a bus?**

The meeting points of various components in a power system are called a 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.

**13. What are the applications of Y-bus matrix?**

- Load flow analysis
- Optimal load flow analysis
- Stability analysis.

**14. What are the applications of Z-bus matrix?**

Short Circuit Analysis (symmetrical and unsymmetrical fault analysis).

**15. What is the purpose of using single line diagram?**

The purpose of the single line diagram is to supply in concise form of the significant information about the system.

**16. What is impedance and reactance diagram?**

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.

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

**17. What are the approximations made in impedance diagram?**

The following approximations are made while forming impedance diagram

(i)The natural reactance's are neglected.

(ii)The shunt branches in equivalent circuit of induction motor are neglected

**18. What is bus impedance matrix?**

The matrix consisting of driving point impedances and transfer impedances Of the network of a power system is called bus impedance matrix.

**19. Write the four ways of adding impedance to an existing system so as to modify bus impedance matrix.**

- Adding a branch of impedance $Z_b$ from a new bus-p to the reference bus.
- Adding a branch of impedance $Z_b$ from a new bus-p to an existing bus-q.
- Adding a branch of impedance $Z_b$ from an existing bus-q to the reference bus.
- Adding a branch of impedance $Z_b$ between two existing buses h and q.

**20. A generator rated at 30 MVA, 11 kV has a reactance of 20%. Calculate it's per unit reactance for a base of 50 MVA and 10 kV.**

New p.u.reactance of generator,

$$X_{pu,new}= X_{pu,old} \text{ x } (kV_{b,old} / kV_{b,new})^2 \text{ x } (MVA_{b,new} / MVA_{b,old})$$

Here, $X_{pu,old}$ =20%=0.2p.u. , $MVA_{b,old}$=30MVA, $MVA_{b,new}$=50MVA,

$kV_{b,old}$ =11KV, $kV_{b,new}$ =50MVA

New p.u.reactance of generator = 0.2 x $(11/10)^2$ x (50/30) =0.403 p.u.

**21. What are the approximations made in impedance diagram? (Or) What are the factors that need to be omitted for an impedance diagram to reduce it to a reactance diagram?**

- The neutral reactance are neglected.
- Shunt branches in the equivalent circuits of transformer are neglected.
- The resistances are neglected.
- All static loads and induction motors are neglected.
- The capacitances of the transmission lines are neglected.

**22. Name the diagonal and off-diagonal elements of bus admittance matrix.**

The diagonal elements of bus admittance matrix are called self admittances of the buses and off-diagonal elements are called mutual admittances of the buses.

Part B

1. Draw the reactance diagram for the ps shown in fig. Neglect resistance and use a base of 50 MVA & 13.8 kV on Generator $G_1$

$G_1$ : 20 MVA, 13.8 kV, $x'' = 20\%$

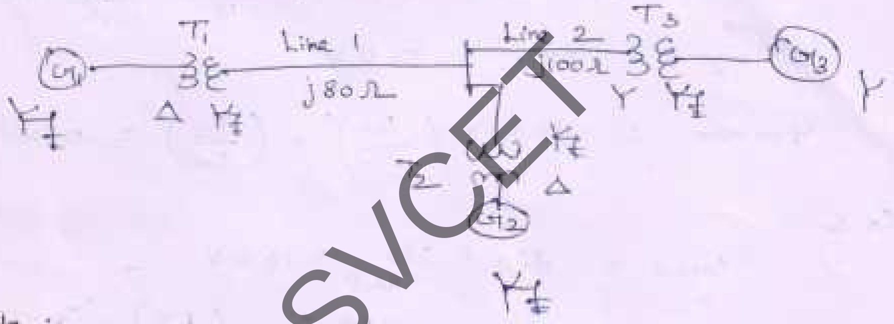
$G_2$ : 30 MVA, 18.0 kV, $x'' = 20\%$

$G_3$ : 30 MVA, 20.0 kV, $x'' = 20\%$

$T_1$ : 25 MVA, 220/13.8 kV, $x = 10\%$

$T_2$ : 3 single phase unit each rated 10 MVA, 127/18 kV $x = 10\%$

$T_3$ : 35 MVA, 220/22 kV, $x = 10\%$



Soln :

$MVA_{b\,new} = 50$ ; $KV_{b\,new} = 13.8$ KV

Formulae used :

$$Z_{p.u\,new} = Z_{pu\,old} \times \left[\frac{KV_{b\,old}}{KV_{b\,new}}\right]^2 \times \left[\frac{MVA_{b\,new}}{MVA_{b\,old}}\right]$$

(Generators) & (Transformers)

$$Z_{p.u\,new} = \frac{Z_{actual}}{KV_{b\,new}^2} \times MVA_{b\,new}$$

(Tr. lines)

For calculating new base kV,

$$KV_{b\,new} = KV_{b\,old} \times \frac{HT\ side\ rating}{LT\ side\ rating}$$

(or)

$$KV_{b\,new} = KV_{b\,old} \times \frac{LT\ side\ rating}{HT\ side\ rating}$$

G1

$$Z_{pu\,new} = j0.2 \times \left(\frac{13.8}{13.8}\right)^2 \times \left(\frac{50}{20}\right)$$

$$= 0.5 \text{ pu}$$

T1 :

$$Z_{pu\,new} = j0.2 \times \left(\frac{13.8}{13.8}\right)^2 \times \left(\frac{50}{25}\right) = 0.2 \text{ pu}$$

$$KV_{bnew} = 13.8 \times \frac{220}{13.8} = 220 \text{ kV}$$

Tr. line 1 : $Z_{pu} = \frac{j80}{(220)^2} \times 50 = 0.0826$ pu

Tr. line 2 : $Z_{pu} = \frac{j100}{(220)^2} \times 50 = 0.1033$ pu

Transformer2 : voltage Rating $= 3 \times \frac{127}{18} = \frac{220}{18}$ kV

$$MVA_{bgn} = 3 \times 10 = 30 \text{ MVA}$$

$$Z_{pu\,new} = j0.1 \times \left(\frac{220}{220}\right)^2 \times \left(\frac{50}{30}\right) = 0.1667 \text{ pu}$$

G2 :

$$KV_{bnew} = 220 \times 18/220 = 18 \text{ kV}$$

$$Z_{pu\,new} = 0.2 \times \left(\frac{18}{18}\right)^2 \times \left(\frac{50}{30}\right)$$

$$= 0.333 \text{ pu}$$

T3 :

$$Z_{pu\,new} = j0.2 \times \left(\frac{220}{220}\right)^2 \times \left(\frac{50}{35}\right) = 0.1429 \text{ pu}$$

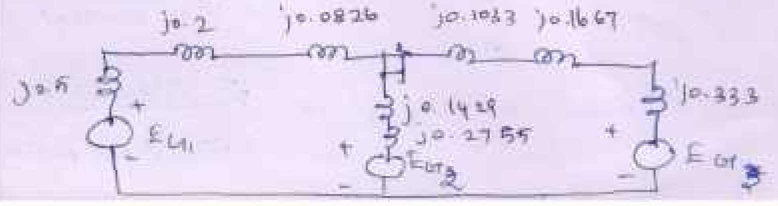
G3 :

$$KV_{bnew} = 220 \times \left(\frac{22}{220}\right) = 22 \text{ kV}$$

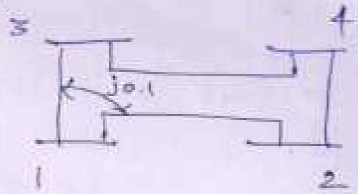
$$Z_{pu\,new} = 0.2 \times \left(\frac{20}{22}\right)^2 \times \left(\frac{50}{30}\right)$$

$$= 0.2755 \text{ pu}$$

Reactance diagram



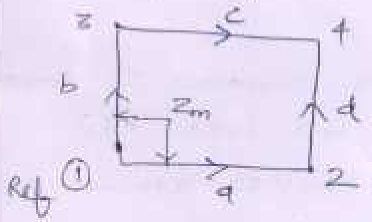
1. Form $Y_{bus}$ of the test system shown in fig. using singular transformation method. The imp. data is gn in table. Take (1) as a ref. node.



| Self | | Mutual | |
|---|---|---|---|
| Bus code | Imp. | Bus code. | Imp |
| 1-2 | 0.5 | | |
| 1-3 | 0.6 | 1-2 | 0.1 |
| 3-4 | 0.4 | | |
| 2-4 | 0.3 | | |

Soln

Oriented Graph:



$$Y_{bus} = [A][Y_{primitive}][A]^T$$

$$\text{Incidence matrix } [A] = \begin{array}{c|cccc} & a & b & c & d \\ \hline (2) & -1 & 0 & 0 & 1 \\ (3) & 0 & -1 & 1 & 0 \\ (4) & 0 & 0 & -1 & -1 \end{array}$$

Primitive impedance matrix,

$$[Z_{primitive}] = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & j0.6 & j0.4 & 0 & 0 \\ b & j0.1 & j0.6 & 0 & 0 \\ c & 0 & 0 & j8.4 & 0 \\ d & 0 & 0 & 0 & j0.3 \end{array}$$

$$[Y_{primitive}] = [Z_{primitive}]^{-1}; \begin{bmatrix} j0.5 & j0.1 \\ j0.1 & j0.6 \end{bmatrix}^{-1} = \cancel{2.0689}$$

$$= \begin{bmatrix} -j2.0689 & j0.3448 \\ j0.3448 & -j1.724 \end{bmatrix}$$

$$[Y_{primitive}] = \begin{bmatrix} -j2.0689 & -j0.3448 & 0 & 0 \\ j0.3488 & -j1.724 & 0 & 0 \\ 0 & 0 & -j2.5 & 0 \\ 0 & 0 & 0 & -j3.33 \end{bmatrix}$$

$$[A]^T = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & & -1 \\ 1 & 0 & -1 \end{bmatrix}$$

$$Y_{bus} = [A][Y_{primitive}][A]^T$$

$$= \begin{bmatrix} -j5.4019 & j0.3448 & j3.333 \\ j0.3448 & -j4.224 & j2.5 \\ j2.83 & j2.5 & -j5.833 \end{bmatrix}$$

3. Describe the $Z_{bus}$ building algorithm in detail by using a three bus system.

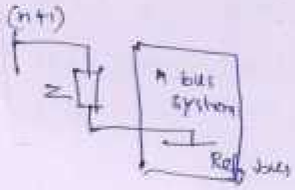
Modification 1 : Add an element with impedance $Z$, connected between the ref. node and a new node $(n+1)$

Modification 2 : Add an element connected between an existing node $i$ and a new node $(n+1)$

Modification 3 : Add an element connected between an existing node $i$ and the ref. node.

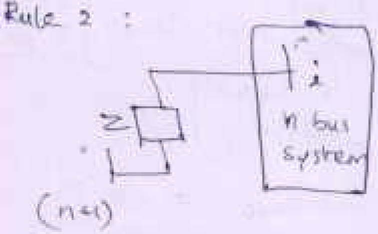
Modification 4 : Add an element connected between existing nodes $i$ and $j$.

Rule 1 :



$$Z_{bus\,new} = \left[\begin{array}{c|c} Z_{bus\,old} & 0 \\ \hline 0 & Z \end{array}\right]$$

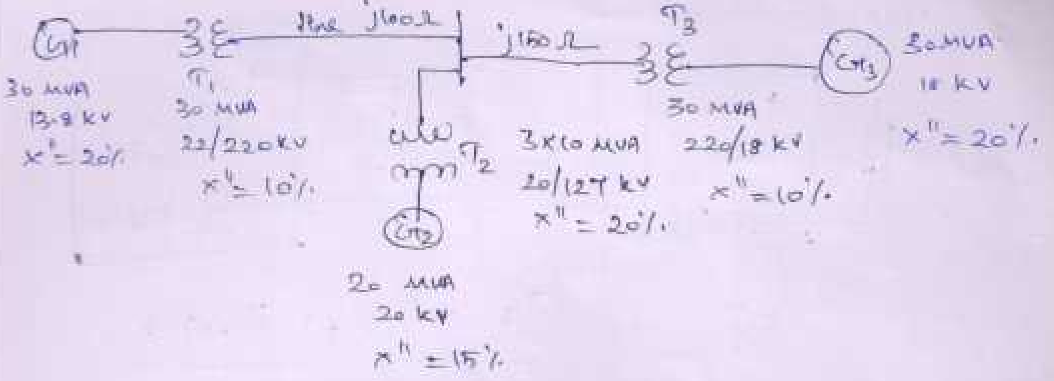
Rule 2 :



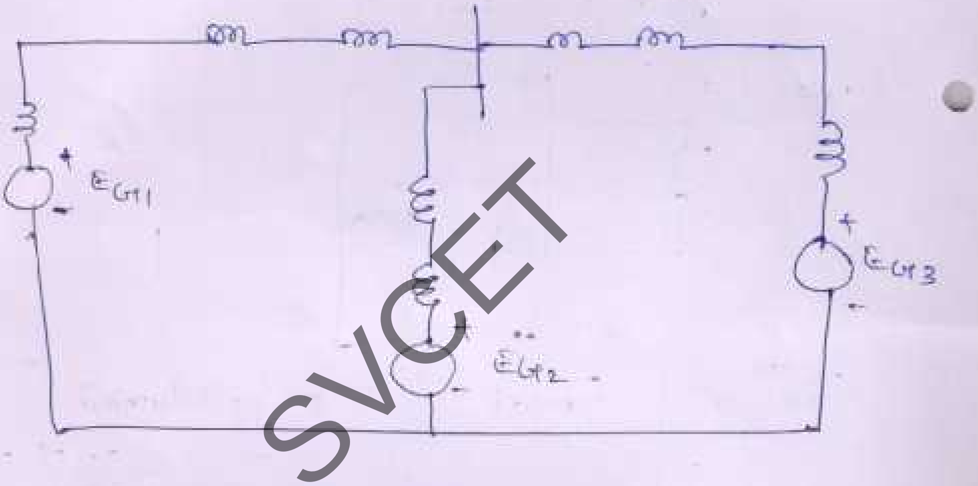
$$Z_{bus\,new} = \left[\begin{array}{c|c} Z_{bus\,old} & Z_i \\ \hline Z_i^T & Z+Z_{ii} \end{array}\right]$$

where $Z_i \Rightarrow$ $i^{th}$ column of $Z_{bus}$

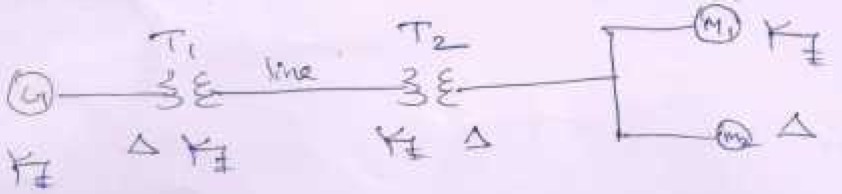
$Z_i^T \Rightarrow$ the transpose of $Z_i$



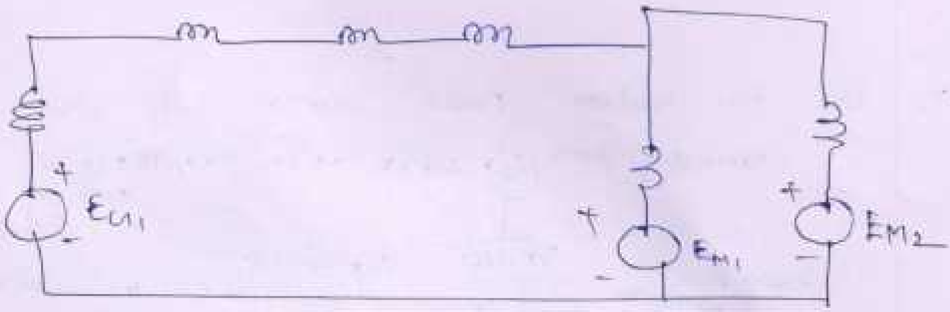
Soln :



5. A 90 MVA, 11 kV 3ϕ Generator has a reactance of 25%. The generator supplies two motors through t/f and tr. line. The t/f T1 is a 3ϕ t/f, 100 MVA, 10/132 kV, 6% reactance. The t/f T2 is composed of 3 single phase units each rated, 300 MVA, 66/10 kV with 5% reactance. The connection of T1 & T2 are shown. The motors are rated at 50 MVA, and 400 MVA both 10 kV and 20% reactance. Taking the generator rating as base, draw reactance diagram and indicate the reactance in p.u. The reactance of line is 100 Ω.

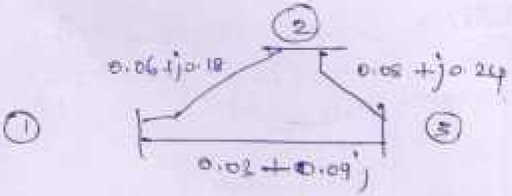


Reactance diagram



6. Determine Ybus for the 3 bus system shown in fig. The line series impedances are follows

| Line | Imp. (p.u) |
|---|---|
| 1-2 | 0.06 + j0.18 |
| 1-3 | 0.03 + j0.09 |
| 2-3 | 0.08 + j0.24 |

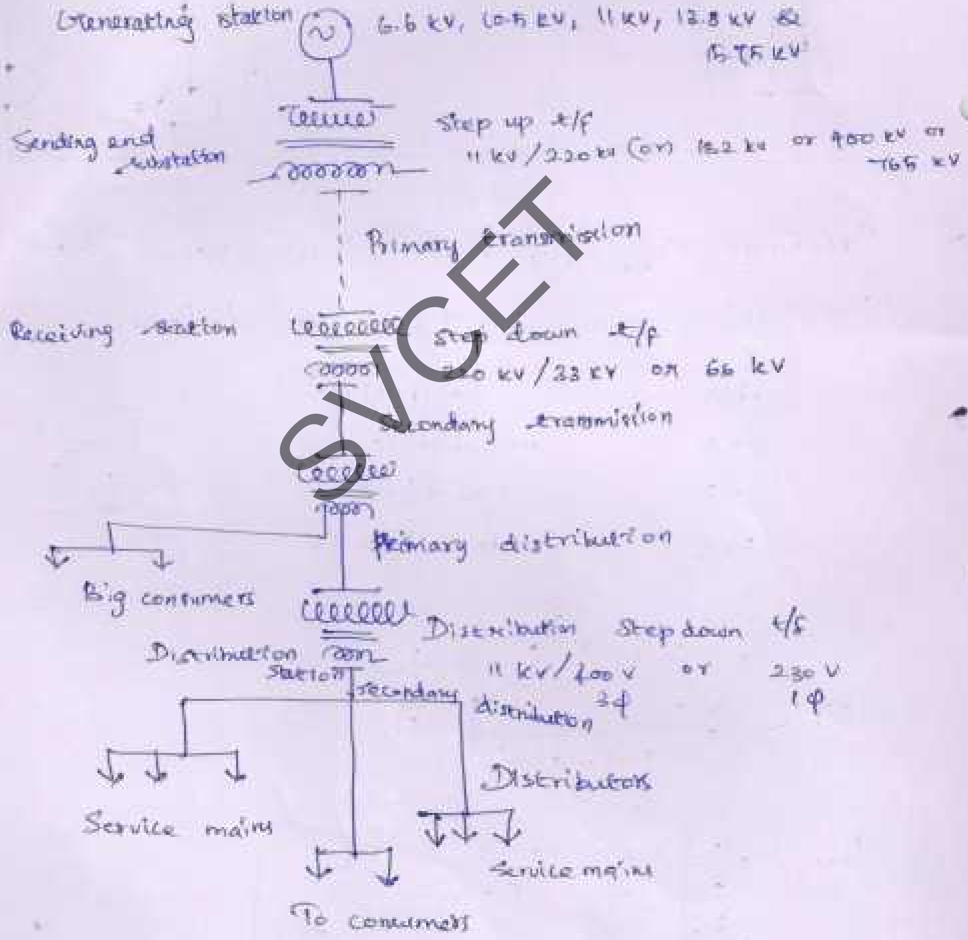


$$Y_{bus} = \begin{array}{c|ccc} & 1 & 2 & 3 \\ \hline 1 & Y_{12}+Y_{13} & -Y_{12} & -Y_{13} \\ 2 & -Y_{12} & Y_{12}+Y_{23} & -Y_{23} \\ 3 & -Y_{31} & -Y_{23} & Y_{23}+Y_{13} \end{array}$$

$$= \begin{bmatrix} \frac{1}{0.06+j0.18} + \frac{1}{0.03+j0.09} & -\left(\frac{1}{0.06+j0.18}\right) & -\left(\frac{1}{0.03+ 0.09j}\right. \\ -\left(\frac{1}{0.06+j0.18}\right) & \frac{1}{0.06+j0.18} + \frac{1}{0.08+j0.24} & -\left(\frac{1}{0.08+ j0.24}\right. \\ -\left(\frac{1}{0.03+0.09j}\right) & -\left(\frac{1}{0.08+j0.24}\right) & \frac{1}{0.08+j0.24} + \frac{1}{0.03+} \end{bmatrix}$$

$Y_{bus}$ =

7. Exp. the modern power system with neat sketch



Power System

- Generation
- Transmission
- Distribution

9. Write short notes on

Single line diagram : the diagramatic representation of power system in which the components are represented by their symbols and the connection between them are represented by straight line.

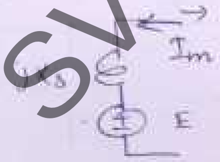
Change of base : when transformer exists in a power system network the change of base should be there.

For G & M, t/f $Z_{pu\,new} = Z_{pu\,old} \times \left(\frac{kV_{b\,old}}{kV_{b\,new}}\right)^2 \times \left(\frac{MVA_{b\,new}}{MVA_{b\,old}}\right)$

For line $Z_{pu\,new} = \frac{Z_{actual}}{(kV_b)^2} \times MVA_b$

Reactance of synchronous machines :

Syn. m/c



Representation of loads :

1. Constant power representation
2. Constant current representation
3. Constant impedance representation