Engineering Excellence for Empowerment

Nadar Saraswathi College of Engineering & Technology

NSCET E-LEARNING PRESENTATION

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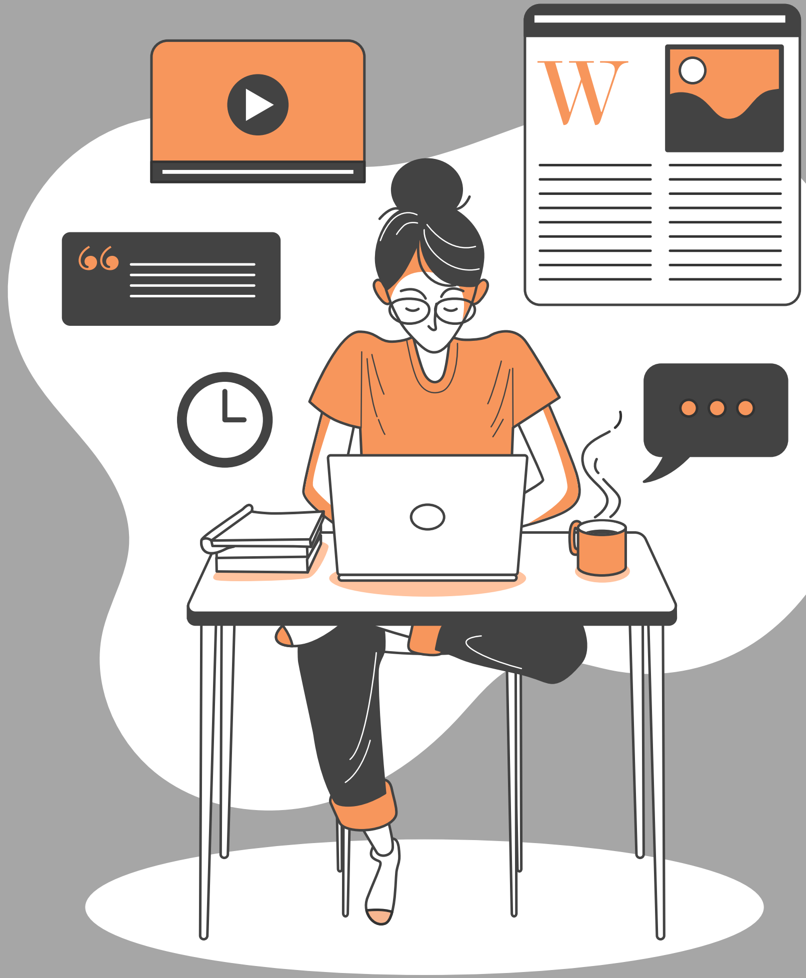

ELECTRICAL AND ELCTRONICS ENGINEERING

III rd YEAR / Vth SEMESTER

EE8501 – Power System Analysis

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UNIT 01 – Power System

Your life is a result of the choices you make .If you don't like the life you have then It's time to make better choices.

-William Shakespeare

UNIT-1

- Need for system planning and operational studies
- Power system components
- Single line diagram
- Per Unit quantities
- P.U impedance diagram
- P.U reactance diagram
- Network graph
- Bus Incidence matrix, primitive parameters
- Bus admittance matrix from primitive parameters

Intrdouction:

Every power system has three major components

- Generation: source of power, ideally with a specified voltage and frequency
- Load: consumes power; ideally with a constant resistive value
- Transmission System: transmits power; ideally as a perfect conductor

Electric utility: Range from quite small, such as an island, to one covering half the continent there are four major interconnected ac power systems in North American, each operating at 60 Hz ac; 50Hz is used in some other countries.

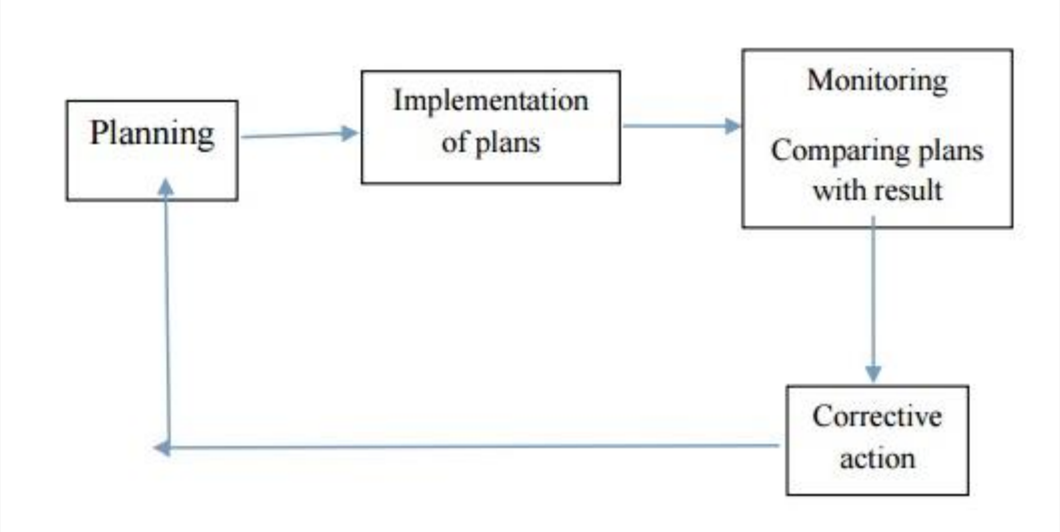
Definition of Power System:

The evaluation of Power system is called as Power system analysis.

Functions of Power system analysis:

- To maintain the voltage at various buses real and reactive power flow between buses.
- To design the circuit breaker.
- To plan the future expansion of existing system
- To analyze the system under different fault conditions (three phase fault, L-G, L-L, L-L-G faults)
- To study the ability of the system for large & small disturbance

Need for system planning and operational studies

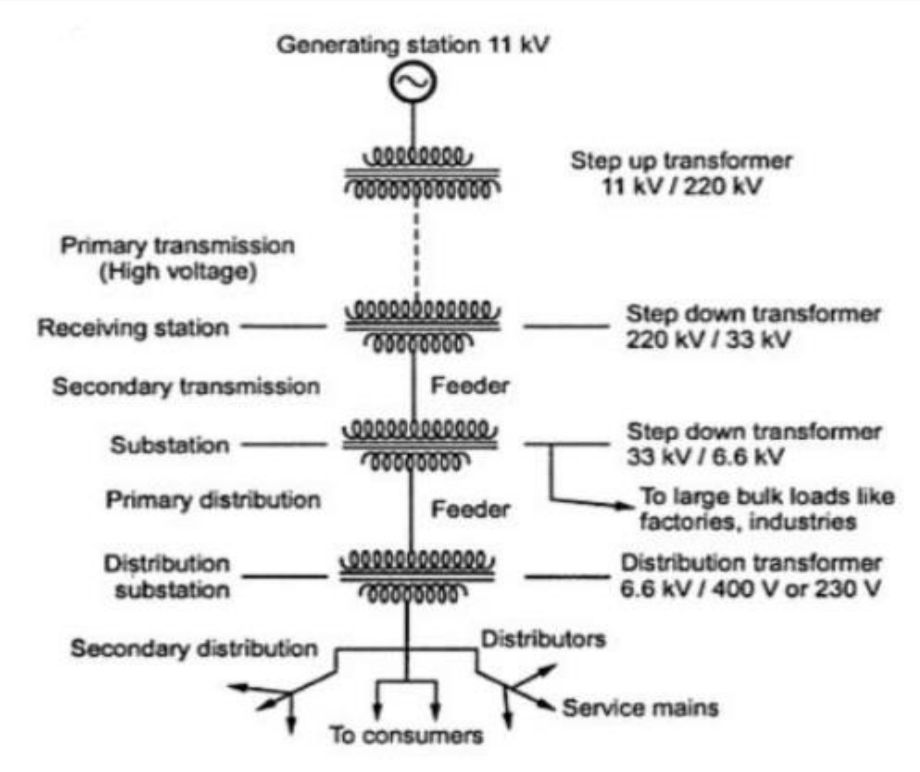


Steps:

- Planning of power system
- Implementation of the plans
- Monitoring system
- Compare plans with the results
- If no undesirable deviation occurs, then directly go to planning of system
- If undesirable deviation occurs then take corrective action and then go to planning Of the system

Power System Components

Structure of Power System

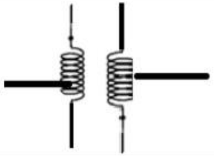
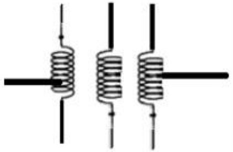
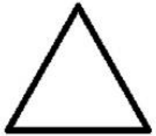


- Generators - Convert mechanical energy in to electrical energy
- Transformers - Transfer Power or energy from one circuit to another circuit with out change in frequency
- Transmission Lines - Transfer power from one place another place
- Control Equipment: Used for protection purpose

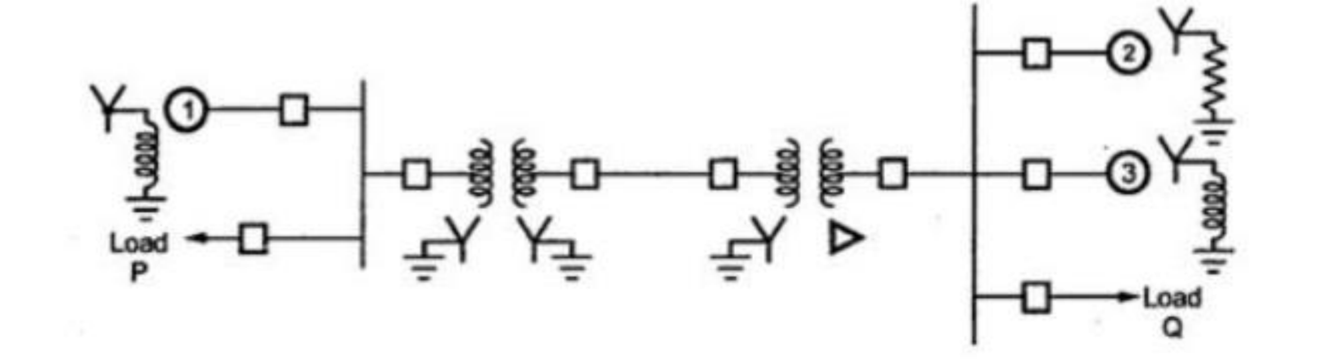
Single Line Diagram

- In general electrical power systems are represented by a one line diagram (or) single line diagram
- A single line diagram of a power system shows the main connections & arrangements of components in a simplified manner
- Pictorial representation of the entire power system from generating end to the consumer premises is known as single line diagram

Standard symbol

Sl.no	Components	Symbol
1	**R**otating M/c(or) armature	
2	Bus	
3	Two winding power Transfomer	
4	Three winding power Transformer	
5	Delta connection (3Φ, 3 wire)	
6	Wye connection (3Φ, neutral un grounded)	
7	Wye connection (3Φ, neutral grounded)	

Single line diagram of an Electrical System



Per Unit Quantities

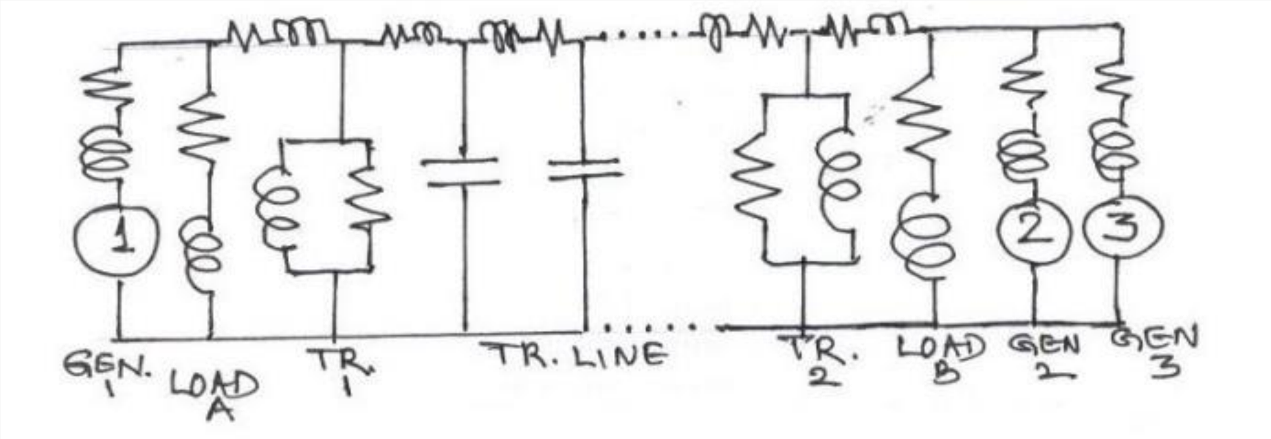
- Per Unit value of a given quantity is the ratio of the actual value in any given unit to the base value in the same unit.

- The percent value is 100 times the pu value. Both the pu and percentage methods are simpler than the use of actual values.

- The main advantage in using the pu system of computations is that the result that comes out of the sum, product, quotient, etc. of two or more pu values is expressed in per unit itself.

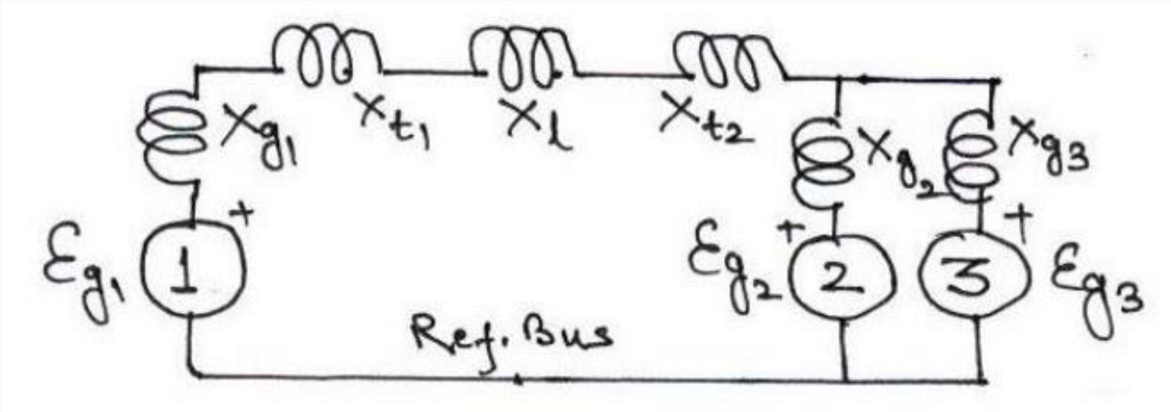
Impedance Diagram:

The impedance diagram on single-phase basis for use under balanced conditions can be easily drawn from the SLD.



Reactance Diagram:

The impedance diagram can be simplified further to obtain the corresponding reactance diagram.



Merits of P.U system:

- The pu value is the same for both 1-phase and & 3-phase systems
- The pu value once expressed on a proper base, will be the same when refereed to either side of the transformer. Thus the presence of transformer is totally eliminated
- The variation of values is in a smaller range 9nearby unity). Hence the errors involved in pu computations are very less.

Demerits of P.U System:

- If proper bases are not chosen, then the resulting pu values may be highly absurd (such as 5.8 pu, -18.9 pu, etc.). This may cause confusion to the user.

PU Impedance / Reactance Diagram

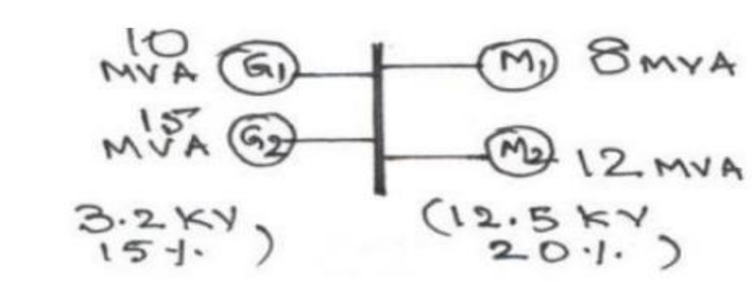
- Obtain the one line diagram based on the given data
- Choose a common base MVA for the system
- Choose a base KV in any one section (Sections formed by transformers)
- Find the base KV of all the sections present
- Find pu values of all the parameters: R,X, Z, E, etc.
- Draw the pu impedance/ reactance diagram.

Problem #1:

Two generators rated 10 MVA, 13.2 KV and 15 MVA, 13.2 KV are connected in parallel to a bus bar. They feed supply to 2 motors of inputs 8 MVA and 12 MVA respectively. The operating voltage of motors is 12.5 KV. Assuming the base quantities as 50 MVA, 13.8 KV, draw the per unit reactance diagram. The percentage reactance for generators is 15% and that for motors is 20%.

<u>Solution</u>

Single line diagram



Selection of base quantities: **50** MVA, **13.8** KV (Given)

Calculation of pu values:

X_{G1} = j 0.15 (50/10) $(13.2/13.8)^2$ = j 0.6862 pu.

X_{G2} = j 0.15 (50/15) $(13.2/13.8)^2$ = j 0.4574 pu.

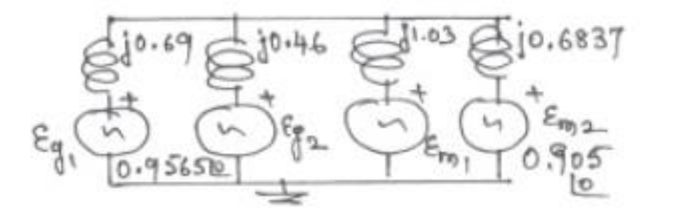
X_{m1} = j 0.2 (50/8) $(12.5/13.8)^2$ = j 1.0256 pu.

X_{m2} = j 0.2 (50/12) $(12.5/13.8)^2$ = j 0.6837 pu.

$E_{g1} = E_{g2}$ = (13.2/13.8) = 0.9565 $\angle 0^0$ pu

$E_{m1} = E_{m2}$ = (12.5/13.8) = 0.9058 $\angle 0^0$ pu

Thus the pu reactance diagram,



Formation of Bus Admittance Matrix

Rule of Inspection

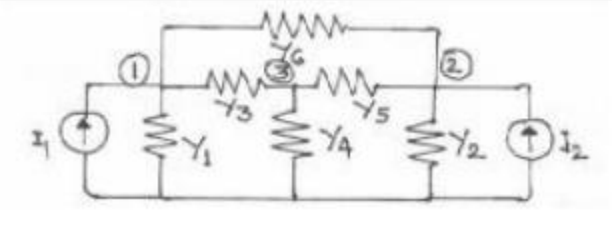
Consider the 3-node admittance network using the basic branch relation:

$I = (YV)$, for all the elemental currents and applying Kirchhoff's Current Law principle at the nodal points, we get the relations as under:

At node 1: $I1 = Y1V1 + Y3\,(V1 - V3) + Y6\,(V1 – V2)$

At node 2: $I2 = Y2V2 + Y5\,(V2 - V3) + Y6\,(V2 – V1)$

At node 3: $0 = Y3\,(V3 - V1) + Y4V3 + Y5\,(V3 – V2)$

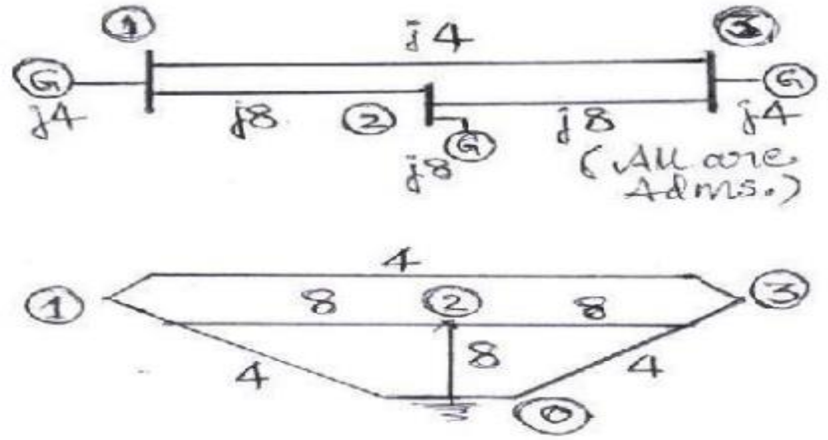


These are the performance equations of the given network in admittance form and they can be represented in matrix form as:

$$\begin{vmatrix} I_1 \\ I_2 \\ 0 \end{vmatrix} \begin{matrix} = \\ = \\ = \end{matrix} \begin{vmatrix} (Y_1+Y_3+Y_6) & -Y_6 & -Y_3 \\ -Y_6 & (Y_2+Y_5+Y_6) & -Y_5 \\ -Y_3 & -Y_5 & (Y_3+Y_4+Y_5) \end{vmatrix} \begin{vmatrix} V_1 \\ V_2 \\ V_3 \end{vmatrix}$$

In other words, the relation can be represented in the form
IBUS = YBUS EBUS
Where, YBUS is the bus admittance matrix, IBUS & EBUS are the bus current and bus voltage vectors respectively.

Problem #2: Obtain the bus admittance matrix for the admittance network shown aside by the rule of inspection



$$
Y_{BUS} = \begin{vmatrix} 16 & -8 & -4 \\ -8 & 24 & -8 \\ -4 & -8 & 16 \end{vmatrix}
$$

Graph Theory

Important Definition in Graph Theory:

- A **graph** shows the geometrical interconnection of the elements of a network.
- A **subgraph** is any subset of elements of the graph.
- A **path** is a subgraph of connected elements with not more than two elements connected to any one node.
- A **tree** is a connected subgraph of a connected graph having all the nodes of the graph but without any closed path (or) loop.

Incidence Matrix

- Every element of a graph is incident between any two nodes. Incidence matrices give the information about incidence of elements—may be incident to loops, cut sets etc. and this information is furnished in a matrix, known as incidence matrix.

- Element-Node Incidence Matrix ($\hat{A}$)

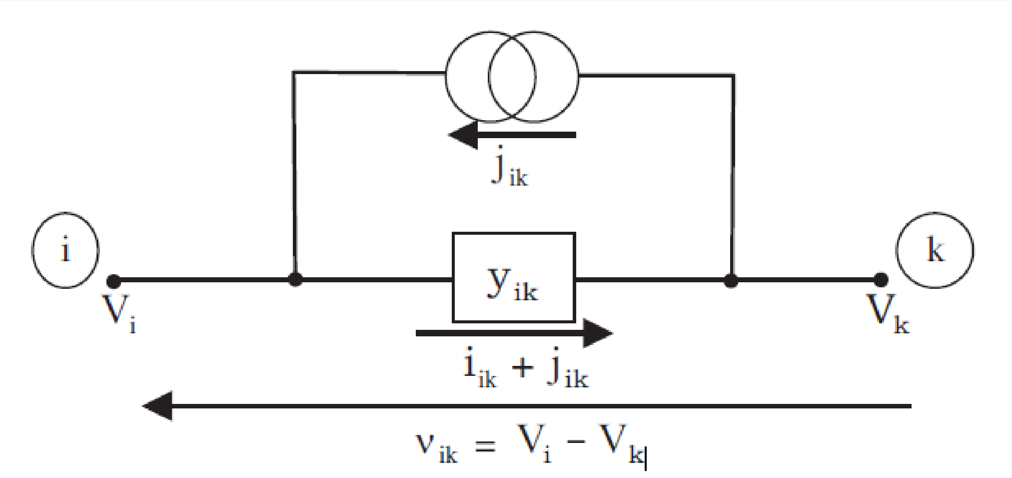
aij = 1 If the ith element is incident to and oriented away from the jth node.

aij = –1 If the ith element is incident to and oriented towards from the jth node.

aij = 0 If the ith element is not incident to the jth node.

Primitive network in admittance form

Let the element i – k connected between the two nodes i and k.
Primitive network,



V_i, V_k → ith and kth node voltages respectively
v_{ik}, $V_i – V_{ik}$ → Voltage across the element i – k
j_{ik} → Source current in parallel with element i – k
i_{ik} → Self-admittance of the element i – k
i_k → Current flowing through the element i – k

Hence, current flowing through the element,

$$i_{ik} + j_{ik} = y_{ik} v_{ik}$$

for all the elements in a condensed form can be written as,

$$i + j = y v$$

Where i, j and v are the column matrices of size e × 1 and matrix y is a square matrix of size e × e.

The matrix y is known as primitive admittance matrix.

$$[z] = \begin{array}{c|ccccc} e \backslash e & 1 & 2 & 3 & 4 & 5 \\ \hline 1 & Z_{11} & & & & \\ 2 & & Z_{22} & & & \\ 3 & & & Z_{33} & & \\ 4 & & & & Z_{44} & \\ 5 & & & & & Z_{55} \end{array} \quad \text{(or)} \quad [y] = \begin{array}{c|ccccc} e \backslash e & 1 & 2 & 3 & 4 & 5 \\ \hline 1 & Z_{11}^{-1} & & & & \\ 2 & & Z_{22}^{-1} & & & \\ 3 & & & Z_{33}^{-1} & & \\ 4 & & & & Z_{44}^{-1} & \\ 5 & & & & & Z_{55}^{-1} \end{array}$$

Primitive impedance matrix

Primitive admittance matrix

If the buses 3 and 4 have mutual element then the corresponding primitive impedance matrix is shown below:

$[z] =$

e \ e	1	2	3	4	5
1	Z_{11}				
2		Z_{22}			
3			Z_{33}	Z_{34}	
4			Z_{43}	Z_{44}	
5					Z_{55}

Primitive impedance matrix

$[y] = [z]^{-1} =$ (or)

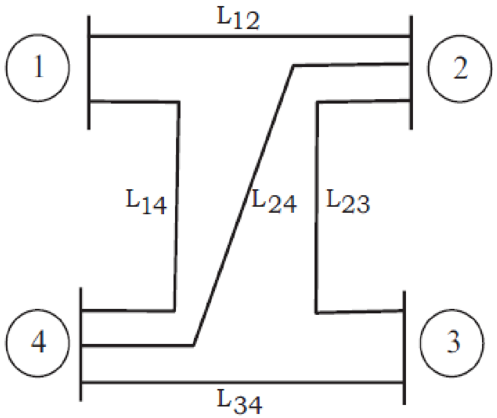
e \ e	1	2	3	4	5
1	Z_{11}^{-1}				
2		Z_{22}^{-1}			
3			$Z_{44}/\Delta Z$	$-Z_{34}/\Delta Z$	
4			$-Z_{43}/\Delta Z$	$Z_{33}/\Delta Z$	
5					Z_{55}^{-1}

Primitive admittance matrix

PROBLEM#3

For the power system shown in fig, build YBus matrix using: (i) by direct inspection, and (ii) singular transformation. The branch impedances of the lines are as follows:

Line	Impedances (Ω)
1 – 2	15 + j40
1 – 4	30 + j50
2 – 3	15 + j25
2 – 4	45 + j20
3 – 4	20 + j30



(i)By using direct inspection method

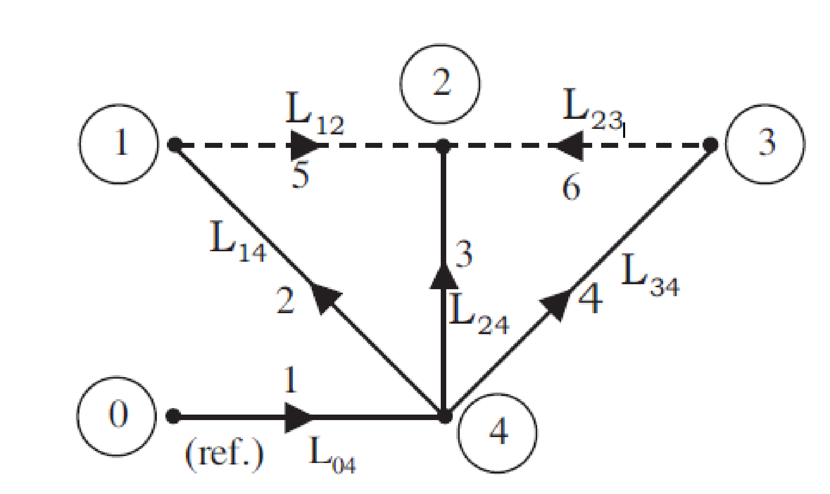
$$Y_{01} = Y_{10} = Y_{02} = Y_{20} = Y_{03} = Y_{30} = Y_{13} = Y_{31} = 0$$

Number of buses are 4, therefore, Y_{Bus} is 4×4 matrix.

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

$$= \begin{bmatrix} 0.0170 - j0.0366 & -0.0082 + j0.0219 & 0 & -0.0088 + j0.0147 \\ -0.0082 + j0.0219 & 0.0444 - j0.0596 & -0.0176 + j0.0294 & -0.0186 + j0.0082 \\ 0 & -0.0176 + j0.0294 & 0.0330 - j0.0525 & -0.0154 + j0.0231 \\ -0.0088 + j0.0147 & -0.0186 + j0.0082 & -0.0154 + j0.0231 & 0.0522 - j0.0594 \end{bmatrix}$$

(ii)By Using Singular Transformation Method



oriented tree graph

Bus incidence matrix

$$
[\hat{A}] = \begin{array}{c|ccccc} e \backslash n & 0 & 1 & 2 & 3 & 4 \\ \hline 1 & 1 & 0 & 0 & 0 & -1 \\ 2 & 0 & -1 & 0 & 0 & 1 \\ 3 & 0 & 0 & -1 & 0 & 1 \\ 4 & 0 & 0 & 0 & -1 & 1 \\ 5 & 0 & 1 & -1 & 0 & 0 \\ 6 & 0 & 0 & -1 & 1 & 0 \end{array} = \begin{bmatrix} 1 & 0 & 0 & 0 & -1 \\ 0 & -1 & 0 & 0 & 1 \\ 0 & 0 & -1 & 0 & 1 \\ 0 & 0 & 0 & -1 & 1 \\ 0 & 1 & -1 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 \end{bmatrix}
$$

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

$$[z]= \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{bmatrix} 35+j50 & 0 & 0 & 0 & 0 & 0 \\ 0 & 30+j50 & 0 & 0 & 0 & 0 \\ 0 & 0 & 45+j20 & 0 & 0 & 0 \\ 0 & 0 & 0 & 20+j30 & 0 & 0 \\ 0 & 0 & 0 & 0 & 15+j40 & 0 \\ 0 & 0 & 0 & 0 & 0 & 15+j25 \end{bmatrix} \end{array}$$

$$[y] = [z]^{-1} = \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array}\begin{bmatrix} 0.0094 - j0.0134 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.0088 - j0.0147 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.0186 - j0.0082 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.0154 - j0.0231 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.0082 - j0.0219 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.0176 - j0.0294 \end{bmatrix}$$

$$\therefore [Y_{Bus}] = [A]^T * [y] * [A] =$$

$$\begin{bmatrix} 0.0170 - j0.0366 & -0.0082 + j0.0219 & 0 & -0.0088 + j0.0147 \\ -0.0082 + j0.0219 & 0.0444 - j0.0596 & -0.0176 + j0.0294 & -0.0186 + j0.0082 \\ 0 & -0.0176 + j0.0294 & 0.0330 - j0.0525 & -0.0154 + j0.0231 \\ -0.0088 + j0.0147 & -0.0186 + j0.0082 & -0.0154 + j0.0231 & 0.0522 - j0.0594 \end{bmatrix}$$

Thank you