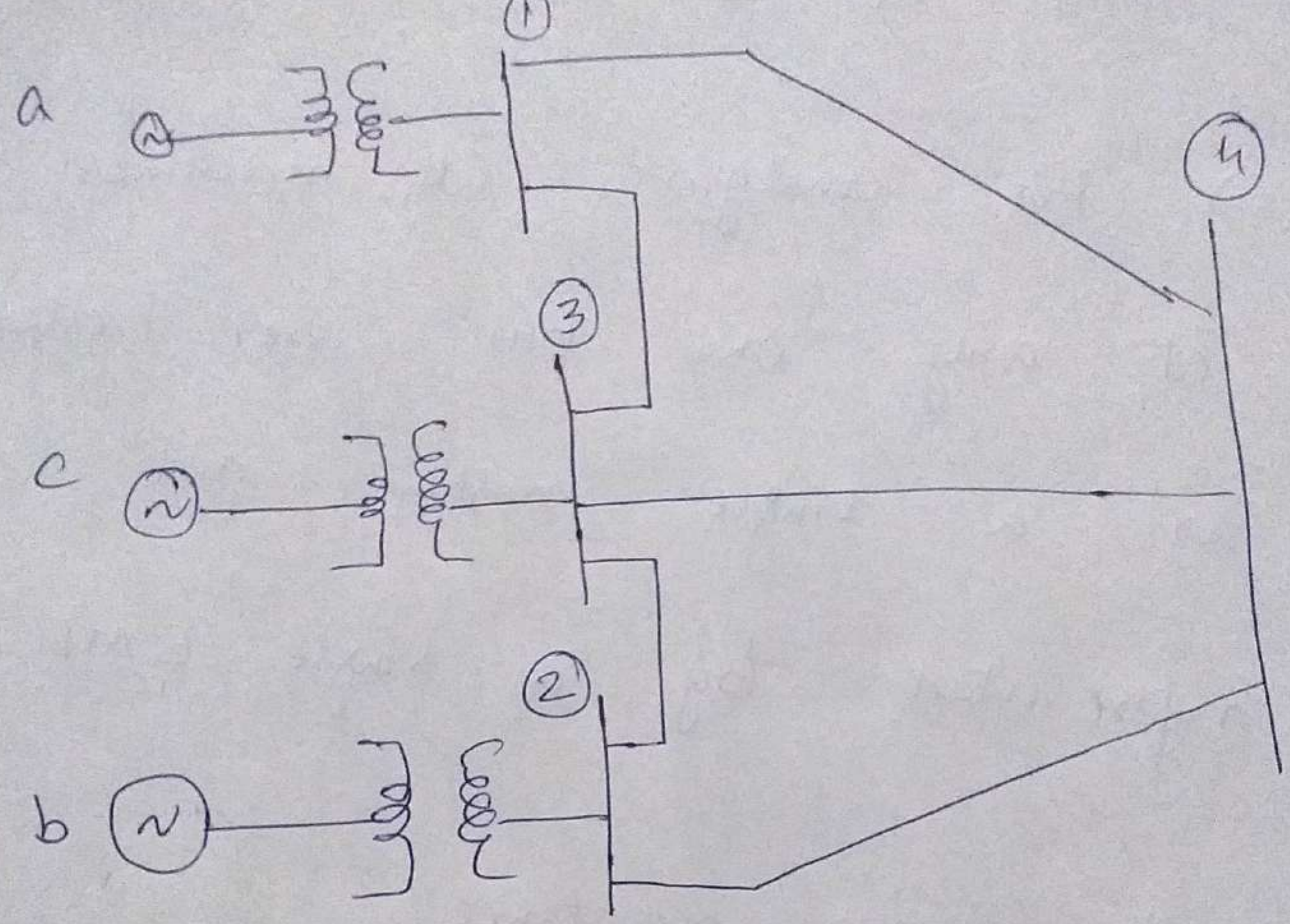
Node Equation:-

⇒ The junction formed when two or more pure elements (R, L and C or an ideal source of Voltage or Current) are connected to each other at their terminals are called Nodes.

⇒ The equations formed at nodes by applying KCL is the basis of computer solution of Power System Problems.

⇒ Usually it is convenient to consider only those nodes to which more than two elements are connected and to call these junctions points major nodes.

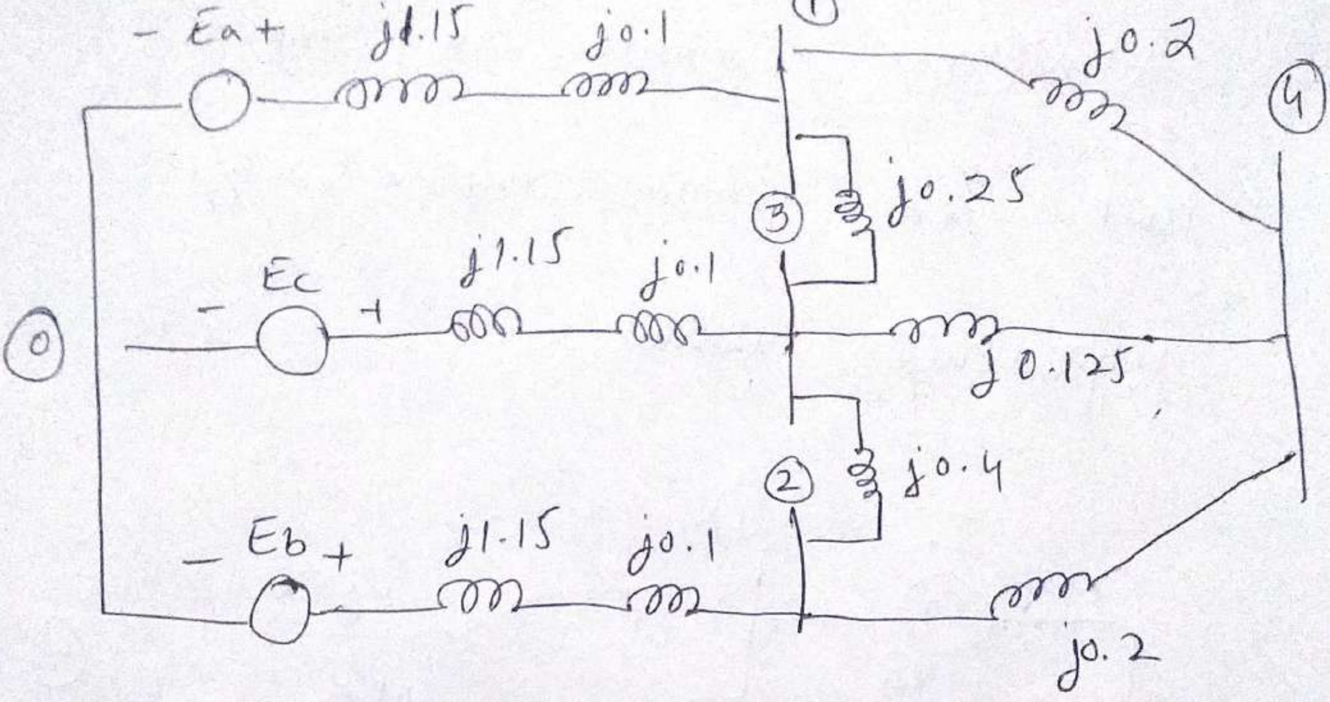
In order to write the node equations. Consider the single line diagram shown on the next page



⇒ Generators are connected through transformers to high tension Buses 1 and 3 and Supply a Synchronous motor load at bus 2.

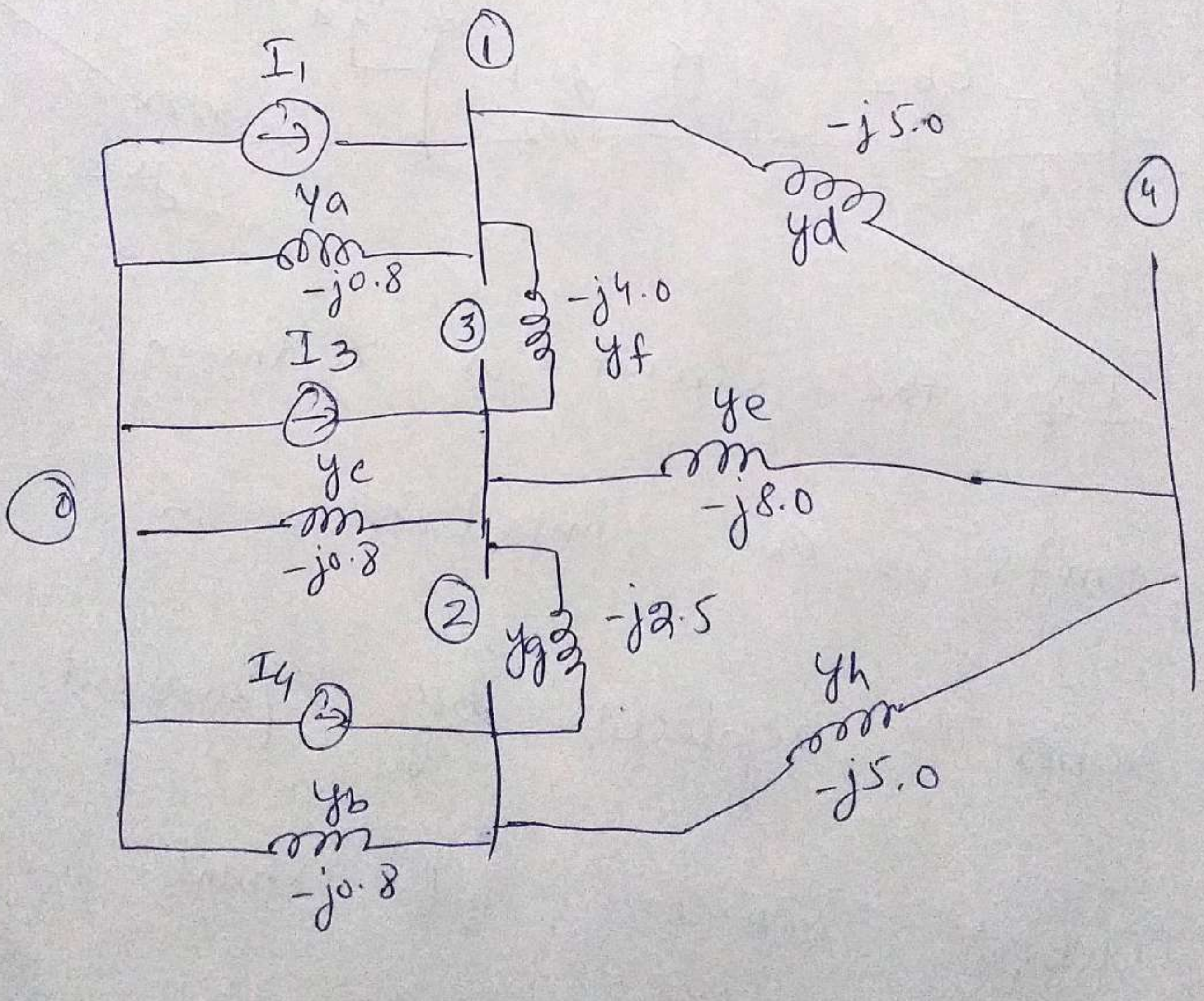
⇒ For analysis, all machines at any one bus are treated as a single machine and represented by a single EMF and series reactance.

⇒ The reactance diagram will be as follows with reactances shown on the next page.



If the circuit is redrawn with emfs and impedences in series replaced by equivalent current sources and shunt admittances, The result is following circuit.

Admittance values in Per unit are shown instead of impedence values.



To designate the voltage of each bus with respect to the neutral.

Take node 0 as a reference.

Applying KCL at node 1.

$$I_1 = V_1 Y_a + (V_1 - V_3) Vf + (V_1 - V_4) Yd$$

$$I_1 = V_1 (Y_a + Y_f + Y_d) - V_3 Vf - V_4 Y_d \rightarrow (1)$$

Similarly at node 2:-

$$I_2 = V_2 (Y_b + Y_g + Y_h) - V_3 Y_g - V_4 Y_h \rightarrow (2)$$

At node 3:-

$$I_3 = V_3 (Y_c + Y_e + Y_f + Y_g) - V_1 Vf - V_4 Y_e + V_2 Y_g \rightarrow (3)$$

$$I_3 = V_3 Y_c + (V_3 - V_1) Y_f + (V_3 - V_2) Y_g$$

$$+ (V_3 - V_4) Y_e$$

$$= V_3 Y_c + V_3 Y_f - V_1 Y_f +$$

$$V_3 Y_g - V_2 Y_g + V_3 Y_e - V_4 Y_e$$

At node 4:-

$$0 = V_4 (Y_d + Y_e + Y_h) - V_1 Y_d -$$

$$V_2 Y_h - V_3 Y_e \rightarrow (4)$$

The standard form for the four independent equations in matrix form.

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} & Y_{14} \\ Y_{21} & Y_{22} & Y_{23} & Y_{24} \\ Y_{31} & Y_{32} & Y_{33} & Y_{34} \\ Y_{41} & Y_{42} & Y_{43} & Y_{44} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix} \rightarrow (5)$$

Equation (5) is designated as Y_{bus} and called the bus admittance matrix. The admittances $Y_{11}, Y_{22}, Y_{33}, Y_{44}$ are called the "self admittances" at the nodes and each equals the sum of all the admittances terminating on the node.

The other admittances are called "mutual admittances" of the nodes and are equal to the negative of the sum of all the admittances connected directly b/w nodes.