**AIM OF EXPERIMENT:** Load flow solution by Mi power software.

**OBJECTIVE:** To compute the voltage and phase angle (phasors) at all the busses in the system, when the terminal conditions are specified.

**THEORY:**

The starting point of any analysis of power system will be the computation of complex voltages at all the busses. Once the complex voltages have been computed the power coming out of a bus and the power flowing in all the transmission lines can be calculated. Load flow analysis is a computational tool for this purpose. Load flow is normally used in planning studies when a power network is being laid or when a power network is undergoing expansion.

Before we start doing load flow analysis, we need to model the entire network with all the generators, loads and transmission lines. A power network is composed of transmission lines (cables), transformers, reactors, loads and generators. A transmission line is represented by an equivalent π circuit with a series impedance (R + jX) from node i to node j as shown in Figure 1.

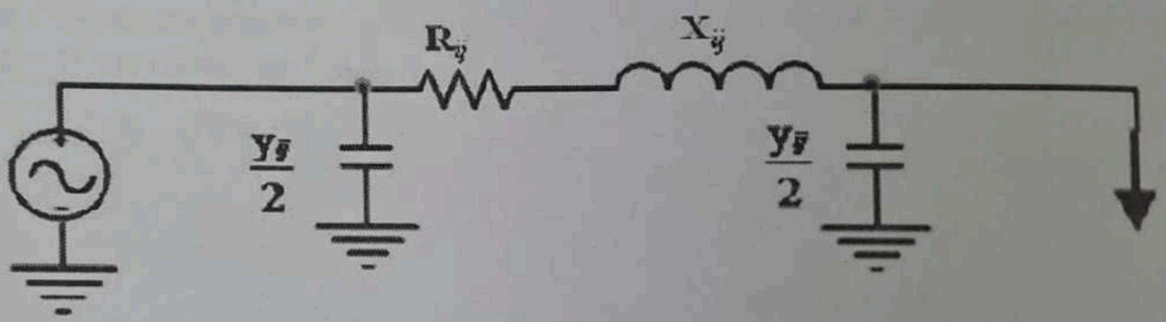



**Figure 1: π circuit model of a transmission line**

The node on the left side has the generator and the node on the right side has the load. $R_{ij}$ and $X_{iji}$ and node *j*. $y_{ij}$ is the shunt charging susceptance of the transmission line. In a short line of low voltage (e.g., up to 80 km), the shunt charging can be neglected. In a medium length high voltage line (e.g., up to 200 km), nominal shunt charging is divided equally at both the ends as shown in Figure 1. are the transmission line series resistance and reactance between node

There are many ways of formulating the power flow equations. The most popular formulation of the network equations is based on the nodal admittance form. The network equations are nonlinear and hence no direct solution is possible. Instead, iterative techniques have to be employed to obtain a solution. Hence good initial estimates of the solution are important. There are many excellent numerical solution methods for solving the power flow problem. The one that has found wide use is the Newton-Raphson method.

Consider the network of Figure 1. The current coming out of nodes (busses) *i* and *j* can be written as

$$I_i = V_i \frac{y_{ij}}{2} + (V_i - V_j)\ (G_{ij} + B_{ij})$$

$$I_j = V_j \frac{y_{ij}}{2} + (V_j - V_i).(G_{ij} + B_{ij})$$

.........(1)

Gij + Bij is the admittance of the transmission line connecting nodes i and j and is the reciprocal of the impedance $R_{ij} + X_{ij}$.

Equation (1) can be re-written as

$$I_i = V_i\ (\frac{y_{ij}}{2} + (G_{ij} + B_{ij}))\ - V_j.(G_{ij} + B_{ij})$$

$$I_j = V_j\ (\frac{y_{ij}}{2} + (G_{ij} + B_{ij}))\ - V_i.(G_{ij} + B_{ij})$$

.............(2)

In the matrix form it can be written as

$$\begin{bmatrix} I_i \\ I_j \end{bmatrix} = \begin{bmatrix} (\frac{y_{ij}}{2} + G_{ij} + B_{ij}) & -(G_{ij} + B_{ij}) \\ -(G_{ij} + B_{ij}) & (\frac{y_{ij}}{2} + G_{ij} + B_{ij}) \end{bmatrix} . \begin{bmatrix} V_i \\ V_j \end{bmatrix}$$

............(3)

The matrix of equation (3) is known as the nodal admittance matrix and is also known as the Y matrix. Any element in the ith row and the $_j$th column of Y matrix is denoted by $Y_{ij}$.

Hence equation (3) would be written as

$$\begin{bmatrix} I_i \\ I_j \end{bmatrix} = \begin{bmatrix} Y_{ii} & Y_{ij} \\ Y_{ji} & Y_{jj} \end{bmatrix} . \begin{bmatrix} V_i \\ V_j \end{bmatrix}$$ ...............(4)

The power (both active and reactive) coming out of a node can be written using the Y matrix. The equation describing this power flow is also known as the load flow equation. It is given as

$$P_i + j\,Q_i = V_i . \sum_j (V_j . Y_{ij})^*$$

......(5)

Pi and Qi are the active and reactive power coming out of node/bus i respectively. The '*' symbol in equation (5) denotes the complex conjugate.

In the polar form equation (5) can be written as

$$P_i + j\,Q_i = |V_i|\angle\delta_i . \sum_j (|V_j|\angle - \delta_j\,|Y_{ij}|\angle - \theta_{ij})$$

.......(6)

Expanding (6) yields,

$$P_i = \sum_j |V_i|\ |V_j|\ |Y_{ij}| \cos(\theta_{ij} + \delta_j - \delta_i)$$

$$Q_i = -\sum_j |V_i|\ |V_j|\ |Y_{ij}| \sin(\theta_{ij} + \delta_j - \delta_i) \qquad \text{........(7)}$$

Let the voltage at node $i$ lead the voltage at node j by angle $\delta$. Then the power flowing from node $ij$ is given by to node

$$P + jQ = \frac{V_i.(V_i - V_j\angle-\delta)^*}{(R + jX)^*}$$

$$\text{or} \quad P + jQ = \frac{V_i.(V_i - V_j(\cos\delta + j\sin\delta))}{(R - jX)} \qquad \text{..........(8)}$$

For a medium length or a long transmission line X >> R. For ease of calculation we can thus ignore R in (10). Rearranging (10) gives us

$$P + jQ = \frac{V_i\ .\ V_j \sin\delta \ + j\, V_i\,(V_i - V_j\cos\delta)}{X}$$

or

$$P = \frac{V_i\ .\ V_j \sin\delta}{X} \quad \text{and} \quad Q = \frac{V_i\,(V_i - V_j\cos\delta)}{X}$$

The active power equation shows that the active power P increases when the power angle δ increases. From an operational point of view, when the operator increases the output of the prime mover to the generator while holding the excitation voltage constant, the rotor speed increases. As the rotor speed increases, the power angle δ also increases, causing an increase in generator active power output P. There is also a decrease in reactive power output Q, given by the reactive power equation. However, when δ is less than 15 degrees, the increase in P is much larger than the decrease in Q.

The reactive power equation demonstrates that reactive power output Q increases when the excitation voltage V increases. From the operational point of view, as the excitation voltage V increases, there is an increase in generator reactive power output Q.From the above equations one can conclude that for small δ, the reactive power output is dependent more on voltage V. Also for voltage magnitudes |V| close to 1.0 pu, the active power output is dependent more on δ.

The power-flow (or load-flow) problem is concerned with finding the static operating conditions of an electric power transmission system while satisfying constraints specified for power and/or voltage at the network buses. Generally, buses are classified as swing bus, PV buses, Load buses and Generator buses. The details of the classifications are given in Table 1.

| Bus Type | Specified Quantities | Comments |
|---|---|---|
| Swing/slack Bus | δ<br>\|V\| | Swing/slack bus is the reference bus. The phase angles of all the other buses are relative to the swing bus angle. The |

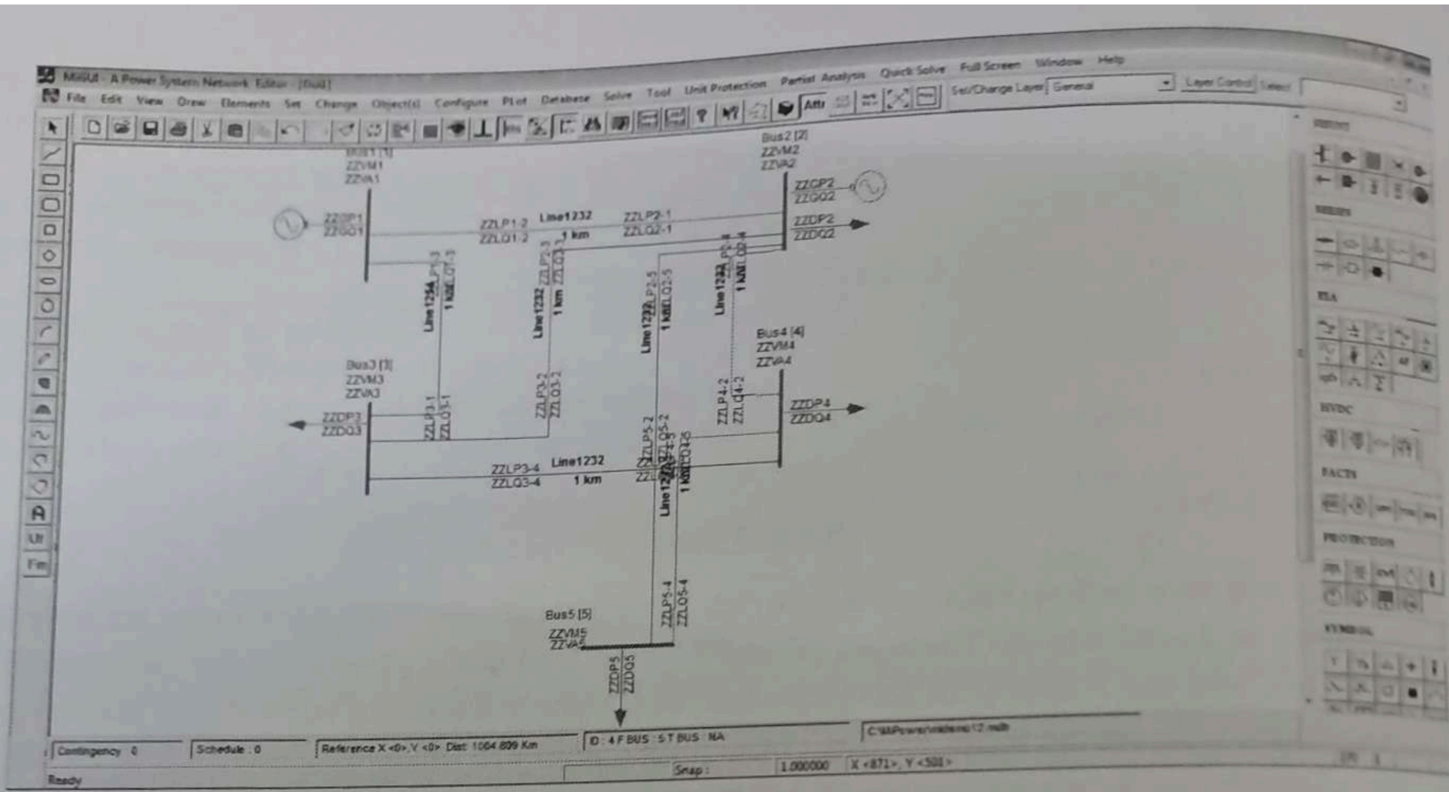
| | | |
|---|---|---|
| | | losses in the network are also considered supplied by the swing bus. Swing bus must also adjust net power to hold voltage constant. |
| PV Bus | P<br>$\|V\|$ | Voltage magnitudes $\|V\|$ at these buses are held constant no matter how much reactive power Q is required. P=0 for a synchronous condenser. |
| Generator Bus | P<br>$\|V\|$<br>Qmax, Qmin | Voltage magnitude $\|V\|$ is held constant as long as Qrequired is within Qmax and Qmin. If Q required crosses the limits, the bus is considered as a PQ bus with Q specified as the Q limit that has been breached. P=0 for a synchronous condenser. |
| PQ or Load Bus | P<br>Q | Normal Load representation. |

As we have seen before, each bus is modeled by two equations. In all, for n buses we have 2n equations in 2n unknowns. These are $|V|$ and $\delta$ at the load buses, Q and $\delta$ at the generator and PV buses, and the P and Q at the slack bus. If we know the phase angle $\delta$ and the voltage magnitudes V for all the buses we don't need to find any other unknowns. Since the slack bus is the reference bus we assign a value of 0 degrees for its $\delta$. The voltage magnitudes for the slack bus, the PV buses and the generator buses are already specified. Hence in reality the number of unknowns that needs to be found out is $2n - 2 - p$, where p is the total number of PV and generator buses. Once the variables $|V|$ and $\delta$ are evaluated for all the buses, the secondary unknowns (P and Q at the slack bus and the reactive powers for the generator and PV buses) can then be evaluated.

Hence the following equations need to be solved.

- Two equations for the active and reactive power for each load buses.
- The active power equation for the PV and generator buses (since V is already specified for these buses.

The Newton-Raphson (NR) method is widely used for solving nonlinear equations. It transforms the original nonlinear problem into a sequence of linear problems whose solutions approach the solution of the original problem.



**PROCEDURE:**

1) Double click on Mi power icon → power system network editor → database → configure → browse → file name → connect → ok
2) Click on bus → choose voltage level → draw bus similarly draw required number of buses.
3) Click on transmission line → click in between two buses → draw transmission line "from bus" to "to bus" , similarly draw all required transmission line put random structure reference number → open transmission line library → give impedance value ( half line charging admittance, if given)
4) Click on generator → connect with slack bus & generator bus. Give random manufacture reference number → open generator library → give MW & MVA (calculated) value.
5) Click on load → connect with load bus. Give the MW & MVA (calculated) value.
6) Solve → load flow analysis → study info (choose method) → execute → report.