



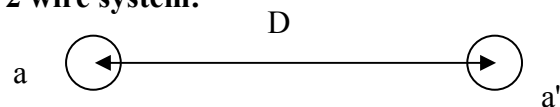
**THEORETICAL CALCULATIONS:**

Exp. No: 1

Date:

**COMPUTATION OF LINE PARAMETERS****AIM:**

To write a “MATLAB” program to determine the line parameters (Inductance/phase and Capacitance/phase) of a single phase, three phase single and double circuit transmission lines for different conductor arrangements.

**1. Single Phase – 2 wire system:****Fig. 1.1 Conductor arrangement**

$$L = 2 \times 10^{-7} \ln\left(\frac{D}{R'}\right) \quad H/m$$

$$C_{an} = \frac{2\pi\xi_o}{\ln(D/R)} F/m$$

Where,

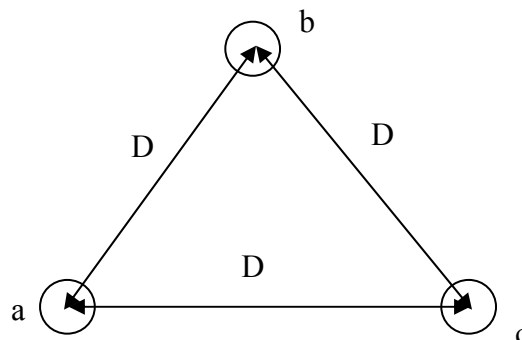
L = Inductance of conductor

 $C_{an}$  = Capacitance of conductor ‘a’ w.r.t neutral

D = Distance between the conductors (m)

 $R' = 0.7788 R$ 

R = Radius of the conductors

 $\epsilon_0$  = Absolute Permittivity =  $8.854 \times 10^{-12}$ **2. Three phase single circuit line – Symmetrical Spacing****Fig. 1.2 Conductor arrangement**

$$L_a = L_b = L_c = 2 \times 10^{-7} \ln\left(\frac{D}{R'}\right) \quad H/m$$

$$C_{an} = \frac{2\pi\xi_o}{\ln(D/R)} F/m$$



Where,

$L$  = Inductance of conductor

$C_{an}$  = Capacitance of conductor 'a' w.r.t neutral

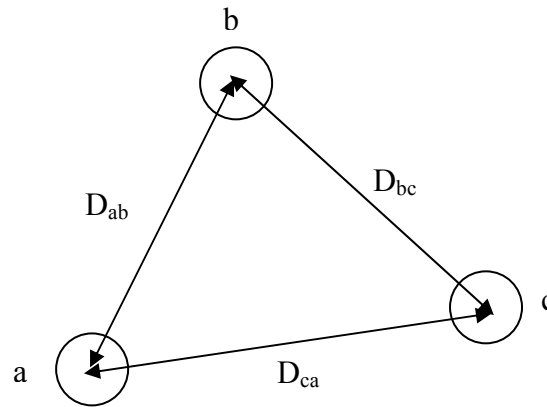
$D$  = Distance between the conductors (m)

$R' = 0.7788 R$

$R$  = Radius of the conductors

$\epsilon_0$  = Absolute Permittivity =  $8.854 \times 10^{-12}$

### 3. Three phase single circuit line –Unsymmetrical spacing



**Fig. 1.3 Conductor arrangement**

$$L_{avg} = 2 \times 10^{-7} \ln \left( \frac{D_{eq}}{R'} \right) \text{ H/m}$$

$$C_{an} = \frac{2\pi\epsilon_0}{\ln(D_{eq}/R)} \text{ F/m}$$

Where,

$L_{avg}$  = Average Inductance of the conductors

$C_{an}$  = Capacitance of conductor 'a' w.r.t neutral

$D_{eq}$  = Equivalent distance between the conductors (m) =  $(D_{ab} * D_{bc} * D_{ca})^{1/3}$

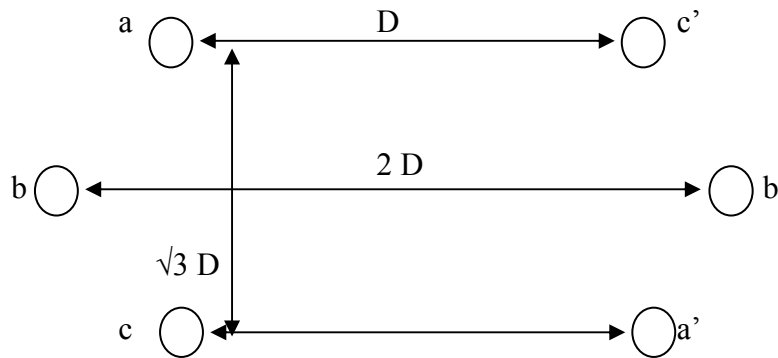
$R' = 0.7788 R$

$R$  = Radius of the conductors

$\epsilon_0$  = Absolute Permittivity =  $8.854 \times 10^{-12}$



#### 4. Three phase – Double Circuit line (symmetrical spacing)



**Fig. 1.4 Conductor arrangement**

$$L_a = L_b = L_c = 2 \times 10^{-7} \ln \left( \frac{\sqrt{3}D}{2R'} \right) \quad H/m$$

$$C_{an} = \frac{2\pi\epsilon_0}{\ln(\sqrt{3}D/2R)} F/m$$

Where,

L = Inductance of conductor

$C_{an}$  = Capacitance of conductor 'a' w.r.t neutral

D = Distance between the conductors (m)

$R' = 0.7788 R$

R = Radius of the conductors

$\epsilon_0$  = Absolute Permittivity =  $8.854 \times 10^{-12}$

#### ALGORITHM:

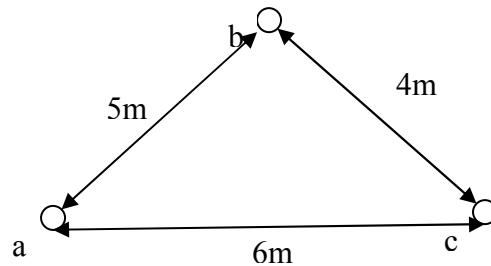
1. Form a menu as follows
  - A. Single phase two wire system
  - B. Three phase single circuit line – Symmetrical Spacing
  - C. Three phase phase single circuit line –Unsymmetrical spacing
  - D. Three phase phase – Double Circuit line (symmetrical spacing)
2. For all the cases, get the required input.
3. Perform necessary calculations.
4. Print the output.



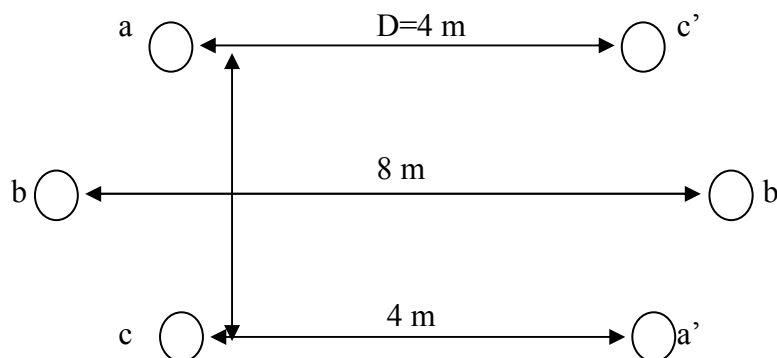


**EXERCISES:**

1. Two wires of single phase transmission line are separated by 3m. The radius of each conductor is 0.02m. Find the inductance and capacitance of each conductor?
2. Determine the inductance and capacitance per phase of a 3-phase transmission line in fig. Diameter of the conductors is 2.5 cm. Assume the line is transposed



3. Find the inductance and capacitance per phase of a double circuit, three phase system as shown in fig. The conductor radius is 2.5cm.

**RESULT:**

Thus, the “MATLAB” program has been written to determine the line parameters (Inductance/phase and Capacitance/phase) of a single phase, three phase single and double circuit transmission lines for different conductor arrangements.

**REFERENCE:**

1. S.N.Singh, ‘Electric Power Generation, Transmission and Distribution’, PHI, New Delhi, 2006.
2. Hadi Saadat, ‘Power System Analysis’, Tata McGraw – Hill Publishing, Co. Ltd., New Delhi, 2002.

**THEORETICAL CALCULATIONS:**

Exp. No: 2

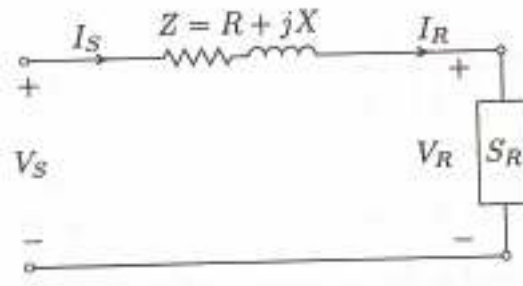
Date:

## MODELLING & PERFORMANCE OF TRANSMISSION LINES

### AIM:

To develop a MATLAB program to analyze the performance of short, medium and long transmission lines by suitably modeling it.

#### 1. Short line Model:



Short line Model

$$(i) \text{ Receiving end current, } I_R = \frac{S_{R(3\phi)}^*}{3V_R^*}$$

$$(ii) \text{ Sending end voltage, } V_S = V_R + ZI_S$$

$$(iii) \text{ Sending end power, } S_{S(3\phi)} = 3V_S I_S^*$$

$$(iv) \text{ Voltage Regulation} = \frac{|V_{R(NL)}| - |V_{R(FL)}|}{|V_{R(FL)}|} \times 100$$

$$(v) \text{ Transmission line Efficiency, } \eta = \frac{P_{R(3\phi)}}{P_{S(3\phi)}}$$

Where,

$S_R$  = Receiving end apparent power

$V_R$  = Receiving end voltage

$Z$  = Line series impedance

$I_S$  = Sending end current

$V_S$  = Sending end voltage

$V_{R(NL)}$  = Receiving end voltage at no-load

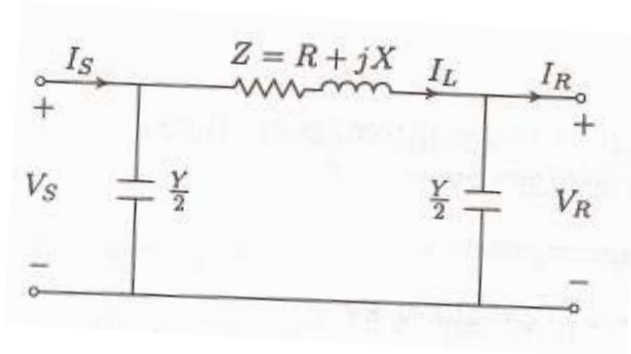
$V_{R(FL)}$  = Receiving end voltage at full-load

$P_R$  = Receiving end real power

$P_S$  = Sending end real power



## 2. Medium line Model:



Medium line Model

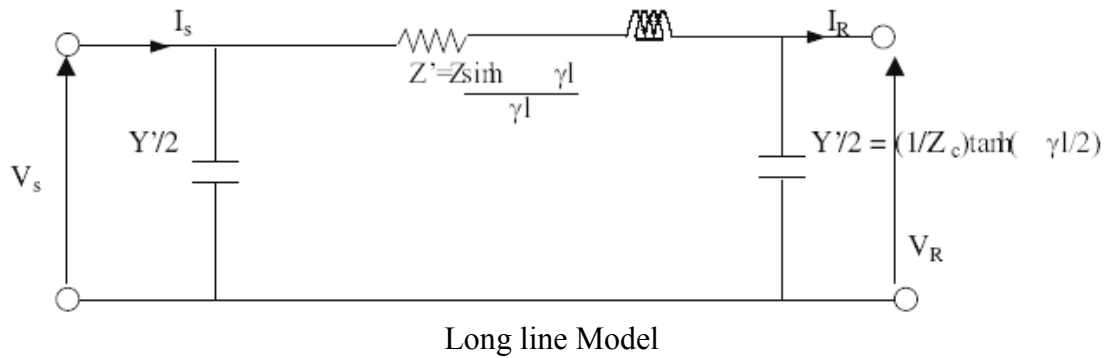
- (i) Receiving end current,  $I_R = \frac{P}{3V_R \cos \phi_r}$
- (ii) Sending end voltage,  $V_S = V_R + ZI_L$
- (iii) Line current,  $I_L = I_r + I_{c1}$
- (iv) Shunt current,  $I_{c1} = \frac{Y}{2} V_R$
- (v) Shunt current,  $I_{c2} = \frac{Y}{2} V_S$
- (vi) Sending end current,  $I_S = I_L + I_{c2}$
- (iii) No-load voltage,  $V_{R(NL)} = \left| \frac{V_S}{1 + (ZY/2)} \right|$
- (iv) Voltage Regulation =  $\frac{|V_{R(NL)}| - |V_{R(FL)}|}{|V_{R(FL)}|} \times 100$
- (v) Transmission line Efficiency,  $\eta = \frac{P}{P + 3I_L^2 R}$

Where,

- P = Receiving end real power
- $V_R$  = Receiving end voltage
- $\cos \phi_r$  = Receiving end power factor
- Z = Line series impedance
- Y = Shunt admittance
- $I_S$  = Sending end current
- $V_S$  = Sending end voltage
- $V_{R(NL)}$  = Receiving end voltage at no-load
- $V_{R(FL)}$  = Receiving end voltage at full-load



### 3. Long line Model:



(i) Characteristic Impedance,  $Z_C = \sqrt{\frac{z}{y}}$

(ii) Propagation constant,  $\gamma = \sqrt{zy}$

(iii) Receiving end current,  $I_R = \frac{P}{3V_R \cos \phi_r}$

(iv) Sending end voltage,  $V_S = V_R \cosh(\gamma l) + Z_C I_R \sinh(\gamma l)$

(vi) Sending end current,  $I_S = \frac{V_R}{Z_C} \sinh(\gamma l) + I_R \cosh(\gamma l)$

(iii) Line parameter,  $A = \cosh(\gamma l)$

(iv) Voltage Regulation =  $\frac{|V_S/A| - |V_R|}{|V_R|} \times 100$

(v) Sending end power factor,  $pf_s = \cos(\angle \text{Voltage} - \angle \text{Current})$

(vi) Input Power =  $3|V_S||I_S| pf_s$

Transmission line Efficiency,  $\eta = \frac{P}{\text{Input Power}}$

Where,

$z$  = Line series impedance

$y$  = Shunt admittance

$P$  = Receiving end real power

$V_R$  = Receiving end voltage

$l$  = Line length

$\cos \phi_r$  = Receiving end power factor

$I_S$  = Sending end current

$V_S$  = Sending end voltage





**ALGORITHM:**

1. Read all the given quantities.
2. Check weather short (or) medium (or) long line.
3. If it is short line, do the calculation as per the formulas given in short line model and find regulation and efficiency.
4. If it is medium line, do the calculation as per the formulas given in medium line model and find regulation and efficiency.
5. If it is long line, do the calculation as per the formulas given in long line model and find regulation and efficiency.

**EXERCISES:**

- (a) A three phase, 60 Hz, 40 km long overhead line supplies a load of 381 MVA at 220 kV, 0.8 pf lagging. The line resistance is  $0.15 \Omega$  per phase per km and line inductance is 1.3263 mH per phase per km. Calculate the receiving end voltage, receiving end current, voltage regulation and efficiency of transmission.
- (b) A 3-phase, 100 km transmission line is delivering 50 MW, 0.8 pf lagging at 132 kV. Each conductor is having resistance 0.1 ohm/km, reactance 0.3 ohm/km and admittance  $3 \times 10^{-6}$  mho/km. If the load is balanced and leakage is neglected, calculate the sending end voltage, sending end PF, efficiency and regulation of the line using nominal  $\pi$  representations.
- (c) A 50 Hz, 400 kV transmission line is 450 km long and having following distributed parameters.  
 $r = 0.033 \text{ ohm/km}$ ,  $L = 1.067 \text{ mH/km}$ ,  $C = 0.0109 \text{ } \mu\text{F/km}$ .  
 It is delivering 420 MW power at 0.95 lagging. Neglecting the leakage conductance, calculate (a) Voltage at sending end (b) Current (c) Sending end PF (d) Regulation of line (e) Efficiency

**RESULT:**

Thus, the MATLAB program has been written to analyze the performance of short, medium and long transmission lines by suitably modeling it.

**REFERENCE:**

1. S.N.Singh, 'Electric Power Generation, Transmission and Distribution', PHI, New Delhi, 2006.
2. Hadi Saadat, 'Power System Analysis', Tata McGraw – Hill Publishing, Co. Ltd., New Delhi, 2002.

**THEORETICAL CALCULATIONS:**

Exp. No: 3

Date:

### FORMATION OF BUS ADMITTANCE MATRIX USING TWO – RULE METHOD

**AIM:**

To develop a ‘MATLAB’ program to form Bus admittance matrix “Y” of a given power network.

**Two-Rule Method for Assembling Y matrix:**

- 1) The diagonal element  $Y_{ii}$  of the matrix is equal to the sum of the admittances of all elements connected to the  $i^{\text{th}}$  node.
- 2) The off-diagonal element  $Y_{ij}$  of the matrix is equal to the negative of the sum of the admittances of all elements connected between the nodes  $i$  and  $j$ .

**Algorithm for Formation of Bus Admittance Matrix**

The algorithm initializes the matrix  $\mathbf{Y}$  with all the elements set to zero. Then read one element of the network at a time and update the matrix  $\mathbf{Y}$  by adding the contribution of that element.

The contribution of transmission line connected between nodes  $k$  and  $m$  to  $\mathbf{Y}$  is

$$Y_{kk} = \sum_{m=0}^n y_{km} \quad \dots m \neq k$$

$$Y_{km} = Y_{mk} = -y_{km}$$
(2.1)

where  $y_{km}$  is the series admittance in p.u. of the line.

The contribution of a transformer connected between nodes  $k$  and  $m$  is

$$Y_{kk} = \frac{y}{a^2}$$

$$Y_{mm} = y$$

$$Y_{km} = Y_{mk} = -\frac{y}{a}$$
(2.2)

The contribution of a shunt element connected to node  $k$  to  $\mathbf{Y}$  is

$$Y_{kk} = y$$
(2.3)

Where,  $y$  is the admittance in p.u of the shunt element. If  $S$  and  $S_o$  are respectively the MVA rating of the shunt element (capacitor) and base MVA chosen for the system; then the shunt admittance is given by,

$$y = 0 + j\left(\frac{s}{s_o}\right) \text{ p.u.}$$



**ALGORITHM:**

Step 1: Initialize  $\mathbf{Y}$  with all elements set to zero

Step 2: Read the line list, one line at-a-time and update  $\mathbf{Y}$  by adding the respective contribution using equation (2.1)

Step 3: Read the transformer list, one transformer at-a-time and update  $\mathbf{Y}$  by adding the respective contribution using equation (2.2)

Step 4: Read the shunt element list, one element at-a-time and update  $\mathbf{Y}$  by adding the respective contribution, equation (2.3)



**EXERCISE:**

BASE MVA =100; No of buses – 6; No of lines -5;  
Transformers -2; Shunt Capacitors -2

**Transmission line data:**

Line ID	Send Bus	Receive Bus No	Resistance p.u.	Reactance p.u	Half line charging suceptance p.u
1	1	6	0.123	0.518	0.0
2	1	4	0.08	0.370	0.08
3	4	6	0.087	0.407	0.0
4	5	2	0.282	0.64	0.09
5	2	3	0.723	1.05	0.0

Transformer data sending bus of a transformer should be at tap side.

Transformer ID No	Send Bus No	Receive Bus No	Resistance p.u.	Reactance p.u.	Tap Ratio
1	6	5	0.0	0.3	0.98
2	4	3	0.0	0.133	0.99

**Shunt Element data :**

Shunt ID	Bus ID	Rated Capacity MVAR(*)
1	4	2.0
2	6	2.5

\*Sign for Capacitor → + Ve  
Sign for Inductor → - Ve

**RESULT:**

Thus, the 'MATLAB' program has been written to form the Bus admittance matrix "Y" of a given power network.

**REFERENCES:**

1. Power System Analysis – Hadi & Sadat (P:190)
2. Power System Analysis – I.J. Nagrath & D.P Kothari

**THEORETICAL CALCULATIONS:**



Exp. No: 4

Date:

### FORMATION OF BUS IMPEDANCE MATRIX USING BUILDING ALGORITHM

**AIM:**

To develop a MATLAB program for forming the bus impedance matrix for a given network using building algorithm.

**THEORY:****Rule 1: Addition of a tree branch to the reference**

Start with the branches connected to the reference node. Addition of a branch 'z<sub>qo</sub>' between a node 'q' and the reference node 'o' to the given Z<sup>new</sup><sub>bus</sub> matrix of order (m\*m), results in the Z<sup>new</sup><sub>bus</sub> matrix of order (m+1)\*(m+1).

$$Z_{bus}^{new} = \begin{bmatrix} Z_{11} & \cdots & Z_{1m} & 0 \\ \vdots & \ddots & 0 & 0 \\ 0 & \cdots & Z_{mm} & 0 \\ 0 & \cdots & 0 & z_{qo} \end{bmatrix}$$

Where,

z = impedance of an element.

This matrix is diagonal with the impedance values of the branches on the diagonal.

**Rule 2: Addition of a tree branch from a new bus to an old bus**

Continue with the remaining branches of the tree connecting a new node to the existing node. Addition of a branch z<sub>pq</sub> between a new node 'q' and the existing node 'p' to the given Z<sup>old</sup><sub>bus</sub> matrix of order (m\*m), results in the Z<sup>new</sup><sub>bus</sub> matrix of order (m+1)\*(m+1).

$$Z_{bus}^{new} = \begin{bmatrix} Z_{11} & \cdots & Z_{1p} & \cdots & Z_{1m} & Z_{1p} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ Z_{p1} & \vdots & Z_{pp} & \cdots & Z_{pm} & Z_{pp} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ Z_{m1} & \cdots & Z_{mp} & \cdots & Z_{mm} & Z_{mp} \\ Z_{p1} & \cdots & Z_{pp} & \cdots & Z_{pm} & Z_{pp} + z_{pq} \end{bmatrix}$$



### Rule 3: Addition of a Co-tree link between two existing buses

When a link with impedance  $Z_{pq}$  is added between two existing nodes 'p' and 'q', we augment the  $Z_{bus}^{old}$  matrix with a new row and a new column.

$$Z_{bus}^{new} = \begin{bmatrix} Z_{11} & Z_{1p} & Z_{1q} & \cdots & Z_{1m} & Z_{1q} - Z_{1p} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ Z_{p1} & Z_{pp} & Z_{pq} & \cdots & Z_{pm} & Z_{pq} - Z_{pp} \\ Z_{q1} & Z_{qp} & Z_{qq} & \cdots & Z_{qm} & Z_{qq} - Z_{qp} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ Z_{m1} & Z_{mp} & Z_{mq} & \cdots & Z_{mm} & Z_{mq} - Z_{mp} \\ Z_{q1} - Z_{p1} & Z_{qp} - Z_{pp} & Z_{qq} - Z_{pq} & \cdots & Z_{qm} - Z_{pm} & Z_{ll} \end{bmatrix}$$

Where,

$$Z_{ll} = Z_{pq} + Z_{pp} + Z_{qq} - 2Z_{pq}$$

The new row and column is eliminated using the relation,

$$Z_{bus}^{new} = Z_{bus}^{old} - \frac{\Delta Z \Delta Z^T}{Z_{ll}}$$

and  $\Delta Z$  is defined as,

$$\Delta Z = \begin{bmatrix} Z_{1q} - Z_{1p} \\ \vdots \\ Z_{pq} - Z_{pp} \\ Z_{qq} - Z_{qp} \\ \vdots \\ Z_{mq} - Z_{mp} \end{bmatrix}$$

When bus 'q', is the reference bus,  $Z_{qi} = Z_{iq} = 0$  (for  $i = 1, m$ ) and the above matrix reduces to,

$$Z_{bus}^{new} = \begin{bmatrix} Z_{11} & \cdots & Z_{1p} & \cdots & Z_{1m} & -Z_{1p} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ Z_{p1} & \cdots & Z_{pp} & \cdots & Z_{pm} & -Z_{pp} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ Z_{m1} & \cdots & Z_{mp} & \cdots & Z_{mm} & -Z_{mp} \\ -Z_{p1} & \cdots & -Z_{pp} & \cdots & -Z_{pm} & Z_{ll} \end{bmatrix}$$



Where,  $Z_{ll} = z_{pq} + Z_{pp}$ , and,

$$\Delta Z = \begin{bmatrix} -Z_{1p} \\ \vdots \\ -Z_{pp} \\ \vdots \\ -Z_{mp} \end{bmatrix}$$

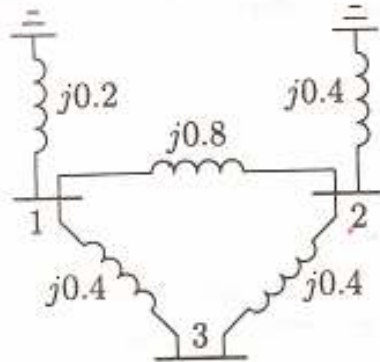
**ALGORITHM:**

1. Start with the branches connected to the reference node using rule 1.
2. Continue with the remaining branches of the tree connecting a new node to the existing node using rule 2.
3. Add the link with impedance  $z_{pq}$  between two existing nodes 'p' and 'q' using rule 3.
4. Check whether all elements connected, if not go to step (1) and continue.
5. Print the  $Z_{BUS}$  matrix.



**EXERCISE:**

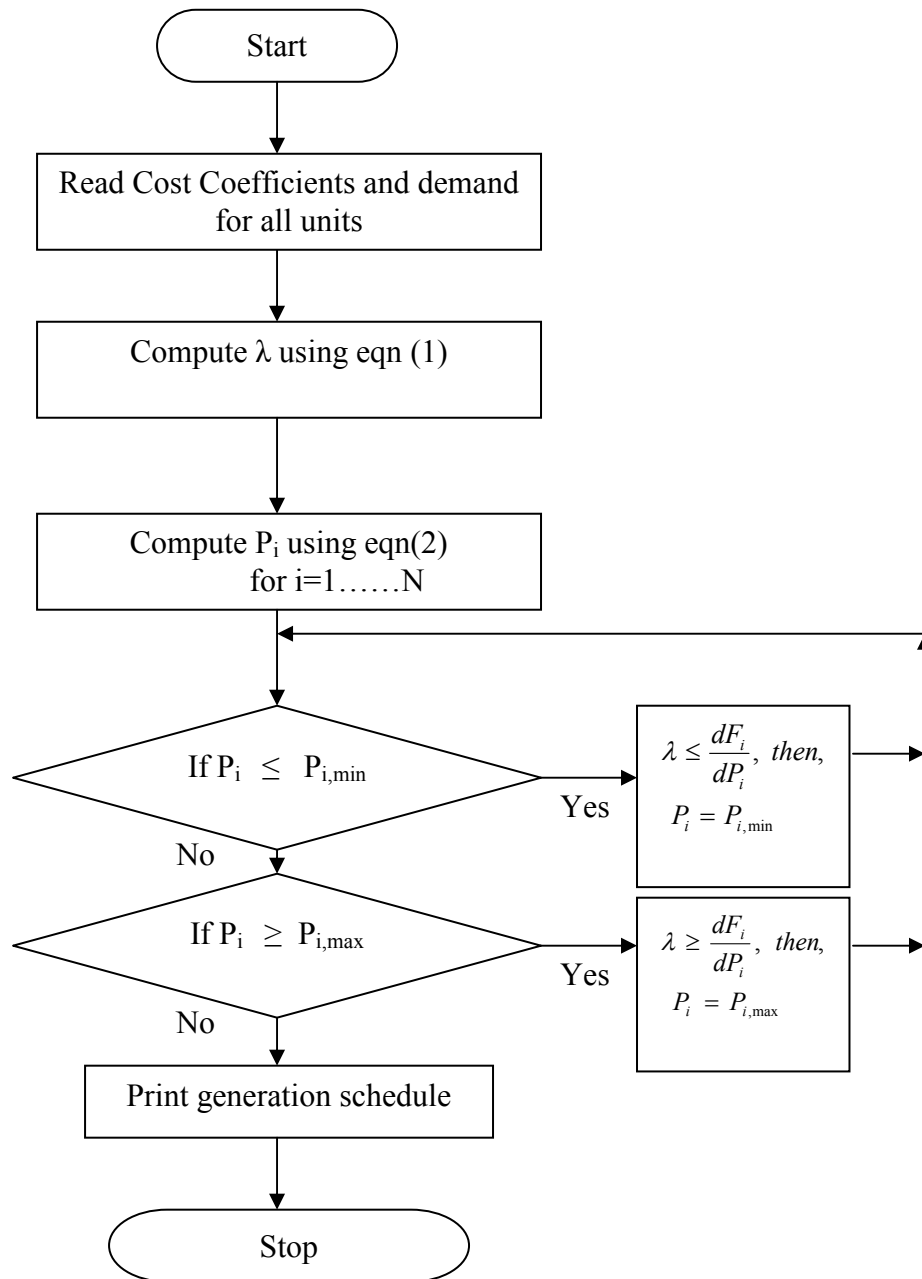
1. For the 3-bus network shown in fig , build  $Z_{BUS}$ .

**RESULT:**

Thus, the MATLAB program has been written to form the bus impedance matrix for a given network using building algorithm.

**REFERENCES:**

1. "Power system Analysis" by Hadi Saadat.
2. "Power system Engineering" I.J.Nagrath and D.P.Kothari

**FLOW CHART:****DIRECT METHOD:**



Exp. No: 5

Date:

## **ECONOMIC LOAD DISPATCH WITHOUT CONSIDERING LOSSES USING DIRECT & LAMBDA ITERATION METHODS**

### **AIM:**

To write a MATLAB program for solving Economic load dispatch problem without considering losses for a given load condition using Direct & Lambda Iteration methods.

### **BASIC KNOWLEDGE REQUIRED:**

- Fuel cost & incremental cost characteristics.
- Economic load dispatch.
- Direct & Lambda Iteration method

### **REFERENCES:**

1. Power Generation, operation & control, Allen. J.Wood and Bruce.F.Wollenberg.
2. "Power system Analysis" by Hadi Saadat.

### **SOFTWARE REQUIRED:**

MATLAB 6.0.

### **SYMBOLS USED:**

$F_i$  = Fuel cost in Rs/hr of  $i^{\text{th}}$  Generator.

$P_i$  = Power Generation of  $i^{\text{th}}$  Generator.

$a_i, b_i, c_i$  = Cost coefficients of  $i^{\text{th}}$  Generator.

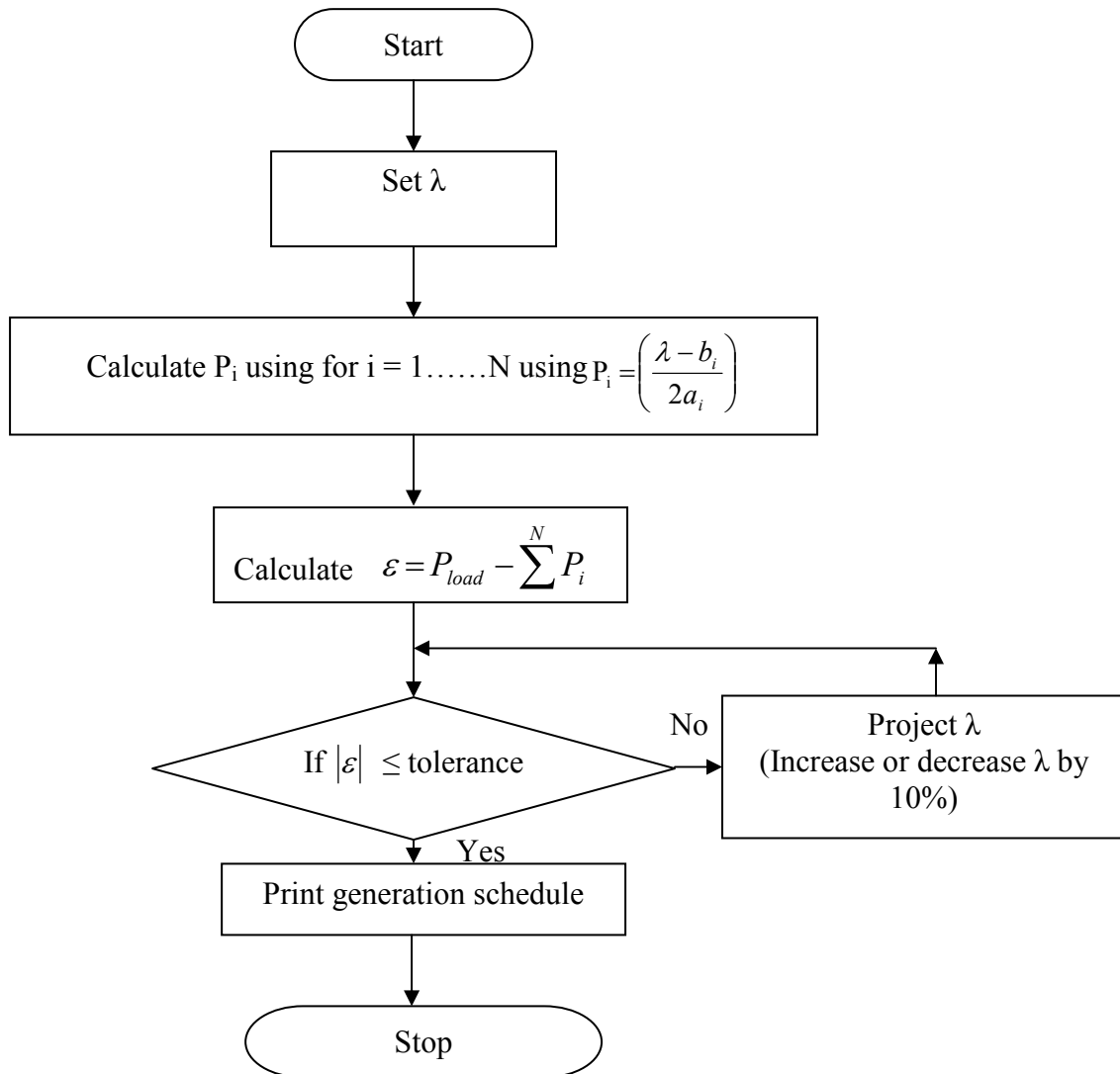
$\lambda$  = Incremental cost of received power in Rs/Mwhr.

$P_D$  = Demand in Mw.

$N$  = Total no of units.

$P_{i,\min}$  = Minimum limit of Generation for  $i^{\text{th}}$  unit in Mw.

$P_{i,\max}$  = Maximum limit of Generation for  $i^{\text{th}}$  unit in Mw.

**FLOW CHART:****LAMBDA ITERATION METHOD:**

**ALGORITHM:****DIRECT METHOD:**

- i. Read Cost coefficients & Demand for all 'N' units.
- ii. Compute  $\lambda$  using the following equation.

$$\lambda = \frac{\left( P_D + \sum_{i=1}^N \left( \frac{b_i}{2a_i} \right) \right)}{\sum_{i=1}^N \left( \frac{1}{2a_i} \right)} \quad (1)$$

- iii. Compute the economic schedule using the following equation.

$$P_i = \left( \frac{\lambda - b_i}{2a_i} \right) \quad (2)$$

- iv. Check if all the PGi satisfy the operating limits.

$$P_{i,\min} \leq P_i \leq P_{i,\max} ; i = 1, 2, \dots, N \quad (3)$$

- v. If  $P_i$  is within the limits, stop the iteration. For the units violating the limits, fix the schedule if,

$$\lambda \geq \frac{dF_i}{dP_i}, \text{ then } P_i = P_{i,\max}, \text{ if } P_i > P_{i,\max}$$

$$\lambda \leq \frac{dF_i}{dP_i}, \text{ then } P_i = P_{i,\min}, \text{ if } P_i < P_{i,\min}$$

- vi. Check whether the optimality condition is satisfied. If the condition is satisfied, then stop the iteration. Otherwise, go to step 1.

**THEORETICAL CALCULATIONS:**

**LAMBDA ITERATION METHOD:**

- i. Read Cost coefficients & Demand for all 'N' units.
- ii. Assume an initial value of  $\lambda$ .
- iii. Compute the economic schedule using the following equation.

$$P_i = \left( \frac{\lambda - b_i}{2a_i} \right)$$

- iv. Calculate the tolerance value,  $\varepsilon = P_{load} - \sum_{i=1}^N P_i$
- v. If  $\varepsilon$  is within the limit, stop the iteration.
- vi. If  $\varepsilon$  is high, increase  $\lambda$  by 10%. If  $\varepsilon$  is low, decrease  $\lambda$  by 10%, and go to step (iii).
- vii. Continue the above procedure until the tolerance value  $\varepsilon$  becomes low.



**EXERCISES:**

1. Determine the economic generation schedules of three generating units in a power system to meet the system load of 850 MW, using direct method. The data of the generating units are given below.

Fuel cost function (In Rs/hr) for three thermal units are given by,,

$$F_1(P_1) = 0.001562 P_1^2 + 7.92 P_1 + 561$$

$$F_2(P_2) = 0.00194 P_2^2 + 7.85 P_2 + 310$$

$$F_3(P_3) = 0.00482 P_3^2 + 7.97 P_3 + 78$$

Operating limits:

$$150MW \leq PG_1 \leq 600MW$$

$$100MW \leq PG_2 \leq 400MW$$

$$50MW \leq PG_3 \leq 200MW$$

2. The fuel cost functions (In Rs/hr) for three thermal units are given by,

$$F_1(P_1) = 0.004 P_1^2 + 5.3 P_1 + 500$$

$$F_2(P_2) = 0.006 P_2^2 + 5.5 P_2 + 400$$

$$F_3(P_3) = 0.009 P_3^2 + 5.8 P_3 + 200$$

Where  $P_1$ ,  $P_2$  and  $P_3$  are in MW. The total load is 800 MW. Neglecting line losses and generator limits, find the optimal dispatch and total cost by Lambda iteration method.

**RESULT:**

Thus, the economic generation schedule without losses, for the given units has been calculated using Direct & Lambda iteration methods.

**REFERENCES:**

1. Power Generation, operation & control, Allen. J.Wood and Bruce.F.Wollenberg.
2. "Power system Analysis" by Hadi Saadat.

**THEORETICAL CALCULATIONS:**



Exp. No: 6

Date:

## **ECONOMIC LOAD DISPATCH WITH LOSSES USING B – COEFFICIENT METHOD**

### **AIM:**

To solve Economic load dispatch problem considering losses for a given load condition by B – Coefficient method using “MiPower” software package.

### **BASIC KNOWLEDGE REQUIRED:**

- Fuel cost & incremental cost characteristics.
- Economic load dispatch.  
B – Coefficient method

### **SOFTWARE REQUIRED:**

- MiPower 4.0

### **STEPS TO BE FOLLOWED:-**

- i. To solve Economic load dispatch using MiPower package, invoke “MiPower Tools” in the MiPower main screen and select “Economic dispatch by B – Coefficient”.
- ii. Select new to create new file.
- iii. Select location to save the file and give the file name.
- iv. Enter the values of total demand, number of generators and the generator details.
- v. Enter initial value of Lambda and B Coefficient values.
- vi. Save and execute to run economic dispatch study.

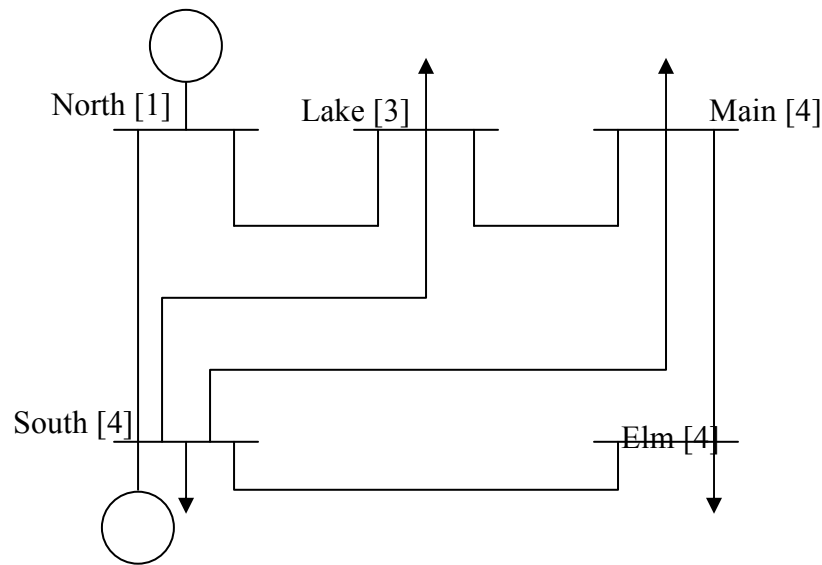






**EXERCISE:**

1. Fig. shows a single line diagram of a 5 bus system with two generating units, seven lines. Per unit transmission line series impedances and shunt susceptances are given on 100 MVA base in Table 1. Real power generation, real and reactive power loads in MW and MVAR are given in Table 2. With bus 1 as slack bus, use the following methods to obtain a load flow solution.
- Gauss – Seidal using Y bus, with acceleration factors of 1.4 and tolerances of 0.0001 and 0.0001 pu for the real and imaginary components of voltage.
  - Newton – Raphson using Y bus, with tolerance of 0.01 pu for the real and reactive bus powers.
- Assume the base voltage for the bus as 220 kV and system frequency as 60 Hz.



Impedances and line charging for the sample system

Table 1		
Bus code From - To	Impedance $R + jX$	Line charging $B / 2$
1 - 2	$0.02 + j0.6$	$0.0 + j0.030$
1 - 3	$0.08 + j0.24$	$0.0 + j0.025$
2 - 3	$0.06 + j0.18$	$0.0 + j0.02$
2 - 4	$0.06 + j0.18$	$0.0 + j0.02$
2 - 5	$0.04 + j0.12$	$0.0 + j0.015$
3 - 4	$0.01 + j0.03$	$0.0 + j0.01$
4 - 5	$0.08 + j0.24$	$0.0 + j0.025$



Generation, loads and bus voltages for sample system

<b>Bus No</b>	<b>Bus Voltage</b>	<b>Generation MW</b>	<b>Generation MVAR</b>	<b>Load MW</b>	<b>Load MVAR</b>
1	1.06 + j0.0	0	0	0	0
2	1.00+ j0.0	40	30	20	10
3	1.00+ j0.0	0	0	45	15
4	1.00+ j0.0	0	0	40	5
5	1.00+ j0.0	0	0	60	10

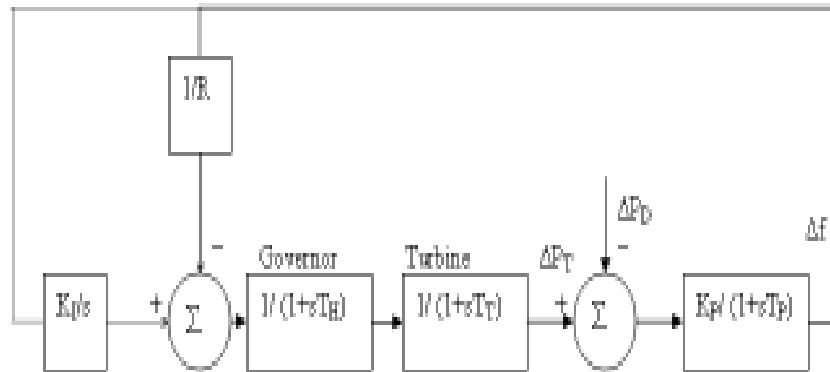
### **RESULT:**

Thus, the Economic load dispatch problem considering losses for a given load condition by B – Coefficient method was studied and the results were verified using MiPower software package.

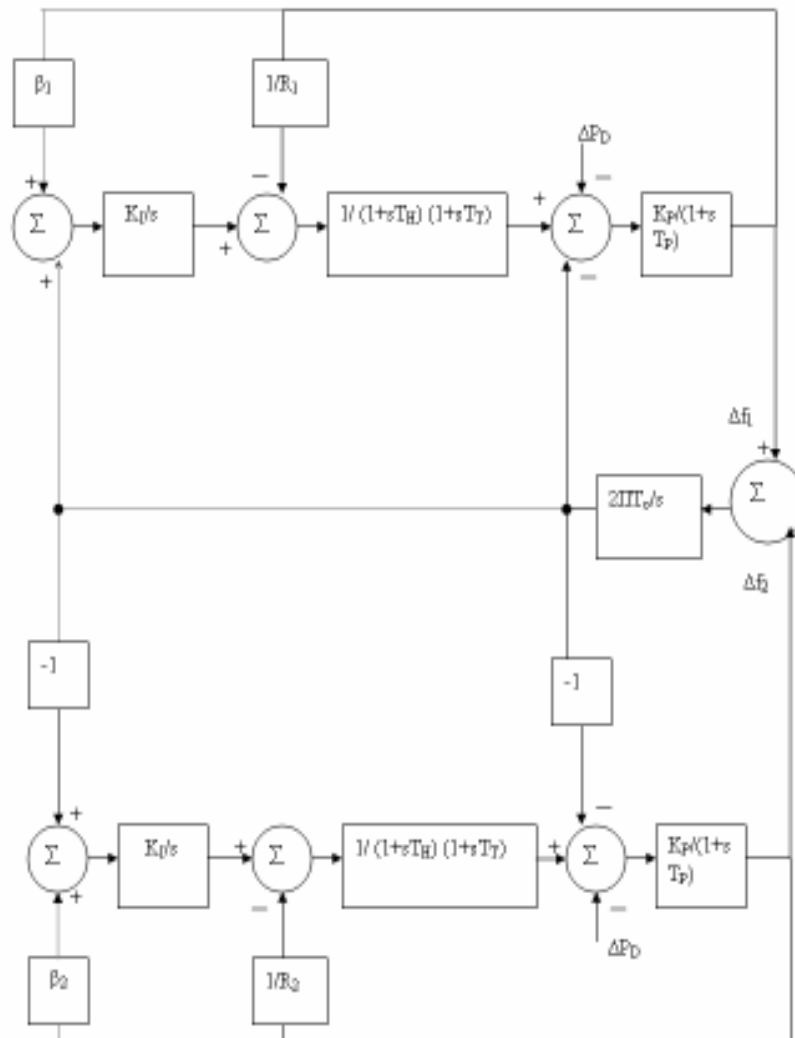
### **REFERENCES:**

1. Power Generation, operation & control, Allen. J.Wood and Bruce.F.Wollenberg.
2. “Power system Analysis” by Hadi Saadat.

**SINGLE AREA SYSTEM**



**TWO AREA SYSTEMS**





Exp. No: 7

Date:

## LOAD FREQUENCY CONTROL OF SINGLE AREA AND TWO AREA SYSTEM

### AIM:

1. To study the time response of area frequency deviation following a single load change in a single area power system provided with an integral frequency controller.
2. To study the time response of area frequency deviation and net interchange deviation following a small load change in any one of areas of an interconnected two area power system.

### BASIC KNOWLEDGE REQUIRED:

- Load frequency control.
- MATLAB Simulink.

### SOFTWARE REQUIRED:

MATLAB 6.0

### NOMENCLATURE:

Turbine time constant =  $T_t$

Governor time constant =  $T_H$

Power system time constant =  $T_p = (2H / D)$

Generator inertia constant =  $H$

Governor Speed regulation =  $R$

Demand change =  $\Delta P_D$

Turbine power increment =  $\Delta P_T$

Power system constant =  $K_p$

Rate of change of load w.r.t frequency =  $D = 1 / K_p$

Synchronizing power coefficient =  $P_s = 2\pi T_o$

### FORMULAH:

Turbine transfer function =  $1 / (1+sT_t)$

Governor transfer function =  $1 / (1+sT_H)$

Power system transfer function =  $1 / (1+sT_p)$

Steady state frequency deviation for single area system =  $\Delta \omega_{ss} = \frac{\Delta P_L}{\left(\frac{1}{R} + D\right)}$

**THEORETICAL CALCULATIONS:**

Steady state frequency deviation for two area system,

$$\Delta\omega_{ss} = \frac{\Delta P_{L1}}{\left(\frac{1}{R_1} + D_1\right) + \left(\frac{1}{R_2} + D_2\right)}$$

**PROCEDURE:**

1. Double click the MATLAB icon.
2. Open a new model file.
3. Open the simulink library from menu.
4. Click on the required components, drag and place one by one in new model file.
5. Connect them and enter the data to form the model of given single area power system.
6. Save and run the model to view the output in the scope. Repeat the same procedure for the given two area power system model.

**EXERCISE:**

1. An isolated power station has the following parameters.

Turbine time constant = 0.5 sec.

Governor time constant = 0.2 sec.

Generator inertia constant, H = 5 sec.

Governor Speed regulation, R = 0.05 pu.

The load varies by 0.8 % for a 1 percent change in frequency, i.e., D = 0.8. The turbine rated output is 250 MW at nominal frequency of 60 Hz. A sudden load change of 50 MW ( $\Delta P_L = 0.2$  pu) occurs.

- i. Find Steady state frequency deviation in Hz.
- ii. Plot the time response of frequency deviation in Hz and change in turbine power.



2. A two area system connected by a tie line has the following parameters on a 1000 MVA common base.

Area	1	2
Speed regulation, R	0.05	0.0625
Freq – sens. Load co-eff, D	0.6	0.9
Inertia constant, H	5	4
Base power	1000 MVA	1000 MVA
Governor time constant, $T_H$	0.2 sec	0.3 sec
Turbine time constant, $T_T$	0.5 sec	0.6 sec

The units are operating in parallel at the nominal frequency of 60 Hz. The synchronizing power coefficient is computed from the initial operating condition and is given to be  $P_s = 2$  pu. A load change of 187.5 MW occurs in area 1.

- i. Find Steady state frequency deviation in Hz.
- ii. Plot the time response of frequency deviation in Hz and change in turbine power.

### RESULT:

Thus, the time response of both single and two area systems were studied and the results were verified using MATLAB Simulink.

### REFERENCES:

1. Elgerd, “Electric Energy System Theory” – An Introduction”, Tata Mc-Graw Hill publishing co .ltd, New Delhi 2003.
2. Hadi Saadat, ‘Power System Analysis’, Tata McGraw – Hill Publishing, Co. Ltd., New Delhi, 2002.

**THEORETICAL CALCULATIONS:**

Exp. No: 8

Date:

**SOLUTION OF LOAD FLOW ANALYSIS USING GAUSS SEIDAL,  
NEWTON RAPHSON AND FAST DECOUPLED METHODS**

**AIM:**

To become proficient in the usage of “MiPower” software for solving load flow analysis using various methods like Gauss Seidal, Newton Raphson and Fast Decoupled methods.

**BASIC KNOWLEDGE REQUIRED:**

- Steady state Load flow analysis.
- Comparison of Gauss Seidal, Newton Raphson and Fast Decoupled methods to solve load flow.

**REFERENCES:**

- Power system analysis – Hadi Saadat.
- Modern Power system analysis – I.J.Nagrath & D.P.Kothari

**SOFTWARE REQUIRED:**

- Mipower 4.0

**NOMENCLATURE:**

$P_i$  = Real power at bus ‘i’

$Q_i$  = Reactive power at bus ‘i’

$V_i$  = Voltage at bus ‘i’

$y_{ij}$  = Admittance between nodes ‘i’ & ‘j’

$P_i^{sch}$  = Net real power at bus ‘i’

$Q_i^{sch}$  = Net reactive power at bus ‘i’

$P_i^{(k+1)}$  = Real power at bus ‘i’ at iteration (k+1)

$Q_i^{(k+1)}$  = Reactive power at bus ‘i’ at iteration (k+1)

$\delta_i^{(k+1)}$  = Voltage angle at bus ‘i’ at iteration (k+1)

$V_i^{(k+1)}$  = Voltage at bus ‘i’ at iteration (k+1)

$\delta_i$  = Voltage angle at bus ‘i’

$\theta_i$  = Admittance angle at bus ‘i’

$J_1, J_2, J_3, J_4$  = Jacobian matrices

$\Delta P_i$  = Change in Real power at bus ‘i’

$\Delta Q_i$  = Change in Reactive power at bus ‘i’

$B', B''$  = Imaginary part of the bus admittance matrix  $Y_{bus}$





**FORMULAH:****1. GAUSS SEIDAL METHOD:**

$$(i) \frac{P_i - jQ_i}{V_i^*} = V_i \sum_{j=0}^n y_{ij} - \sum_{j=1}^n y_{ij} V_j \quad j \neq i$$

$$(ii) V_i^{(k+1)} = \frac{\frac{P_i^{sch} - jQ_i^{sch}}{V_i^{*(k)}} + \sum y_{ij} V_j^{(k)}}{\sum y_{ij}} \quad j \neq i$$

$$(iii) P_i^{(k+1)} = \Re \left\{ V_i^{*(k)} \left[ V_i^{(k)} \sum_{j=0}^n y_{ij} - \sum_{j=1}^n y_{ij} V_j^{(k)} \right] \right\} \quad j \neq i$$

$$(iv) Q_i^{(k+1)} = -\Im \left\{ V_i^{*(k)} \left[ V_i^{(k)} \sum_{j=0}^n y_{ij} - \sum_{j=1}^n y_{ij} V_j^{(k)} \right] \right\} \quad j \neq i$$



## 2. NEWTON RAPHSON METHOD:

$$(i) P_i = \sum_{j=1}^n |V_i| |V_j| |Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j)$$

$$(ii) Q_i = - \sum_{j=1}^n |V_i| |V_j| |Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j)$$

$$(iii) \begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \begin{bmatrix} \frac{\partial P_2^{(k)}}{\partial \delta_2} & \dots & \frac{\partial P_2^{(k)}}{\partial \delta_n} & \frac{\partial P_2^{(k)}}{\partial |V_2|} & \dots & \frac{\partial P_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial \delta_2} & \dots & \frac{\partial P_n^{(k)}}{\partial \delta_n} & \frac{\partial P_n^{(k)}}{\partial |V_2|} & \dots & \frac{\partial P_n^{(k)}}{\partial |V_n|} \\ \frac{\partial Q_2^{(k)}}{\partial \delta_2} & \dots & \frac{\partial Q_2^{(k)}}{\partial \delta_n} & \frac{\partial Q_2^{(k)}}{\partial |V_2|} & \dots & \frac{\partial Q_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial Q_n^{(k)}}{\partial \delta_2} & \dots & \frac{\partial Q_n^{(k)}}{\partial \delta_n} & \frac{\partial Q_n^{(k)}}{\partial |V_2|} & \dots & \frac{\partial Q_n^{(k)}}{\partial |V_n|} \end{bmatrix} \begin{bmatrix} \Delta \delta_2^{(k)} \\ \vdots \\ \Delta \delta_n^{(k)} \\ \Delta |V_2^{(k)}| \\ \vdots \\ \Delta |V_n^{(k)}| \end{bmatrix}$$

$$(i.e) \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix}$$

$$(iv) \Delta P_i^{(k)} = P_i^{sch} - P_i^{(k)}$$

$$(v) \Delta Q_i^{(k)} = Q_i^{sch} - Q_i^{(k)}$$

$$(vi) \delta_i^{(k+1)} = \delta_i^{(k)} + \Delta \delta_i^{(k)}$$

$$(vii) |V_i^{(k+1)}| = |V_i^{(k)}| + \Delta |V_i^{(k)}|$$



### 3. FAST DECOUPLED METHOD

$$(i) P_i = \sum_{j=1}^n |V_i| |V_j| |Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j)$$

$$(ii) Q_i = - \sum_{j=1}^n |V_i| |V_j| |Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j)$$

$$(iii) \Delta P_i^{(k)} = P_i^{sch} - P_i^{(k)}$$

$$(iv) \Delta Q_i^{(k)} = Q_i^{sch} - Q_i^{(k)}$$

$$(v) \Delta \delta = -[B']^{-1} \frac{\Delta P}{|V|}$$

$$(v) \Delta |V| = -[B'']^{-1} \frac{\Delta Q}{|V|}$$

$$(vi) \delta_i^{(k+1)} = \delta_i^{(k)} + \Delta \delta_i^{(k)}$$

$$(vii) |V_i^{(k+1)}| = |V_i^{(k)}| + \Delta |V_i^{(k)}|$$

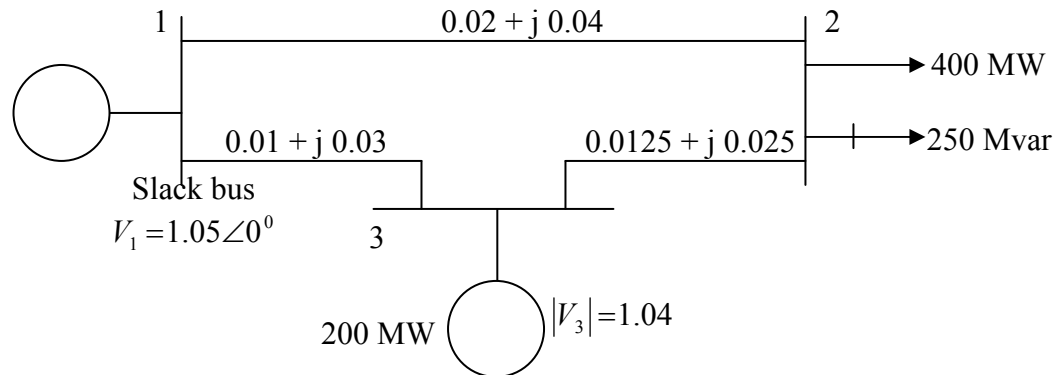
#### STEPS TO BE FOLLOWED:-

- (i) Open power system Network Editor in MiPower.
- (ii) Configure the database
- (iii) Draw the elements of single line diagram from the available blocks and enter the data simultaneously.
- (iv) Solve load flow Analysis using Gauss Seidal method and print the bus Voltage magnitudes, Voltage angles, real and reactive power values at each bus.
- (v) Solve load flow Analysis using Newton Raphson method and print the bus Voltage magnitudes, Voltage angles, real and reactive power values at each bus.
- (vi) Solve load flow Analysis using fast decoupled method and print the bus Voltage magnitudes, Voltage angles, real and reactive power values at each bus.



**EXERCISE:**

1. Fig. shows the one-line diagram of a simple three bus power system with generators at buses 1 and 3. The magnitude of voltages at bus 1 is adjusted to 1.05 pu. Voltage magnitude at bus 3 is fixed at 1.04 pu with a real power generation of 200 MW. A load consisting of 400 MW and 250 Mvar is taken from bus 2. Line impedances are marked in pu on a 100 MVA base, and the line charging susceptances are neglected. Obtain the power flow solution by,
- Gauss-Seidal method.
  - Newton Raphson method and
  - Fast Decoupled method.

**RESULT**

Thus, the Load flow Analysis was done using the Gauss Seidal, Newton Raphson and Fast Decoupled methods.

**REFERENCES:**

- “Power system Analysis” by Hadi Saadat.
- “Power system Engineering” I.J.Nagrath and D.P.Kothari

**THEORETICAL CALCULATIONS:**



Exp. No: 9

Date:

## **SYMMETRICAL & UNSYMMETRICAL FAULT ANALYSIS**

### **AIM:**

To become proficient in the usage of “Power World Simulator” to find the fault currents during Symmetrical and Unsymmetrical faults.

### **BASIC KNOWLEDGE REQUIRED:**

- Importance and usefulness of fault analysis.
- Symmetrical fault.
- Unsymmetrical fault
- Short circuit capacity.

### **SOFTWARE REQUIRED:**

- Power World Simulator

### **ALGORITHM:**

1. Get the following data
  - (a) Sub transient reactance values of Generators.
  - (b) Positive sequence reactance values of Transformers.
  - (c) Positive sequence reactance values of transmission lines.
2. Form the Thevenin’s equivalent circuit under fault condition.
3. Using the Thevenin’s equivalent circuit, find the fault currents for Symmetrical fault, Single line to ground fault, Line to ground fault and Double line to ground fault.

### **STEPS TO BE FOLLOWED:**

1. Open the power world simulator.
2. Open a new case in the file menu.
3. Draw the elements of single line diagram from the available blocks and enter the data simultaneously.
4. Simulate the required fault and solve short circuit studies.
5. Print the report.
6. Study the performance of the system for various fault conditions given below.
  - Line – ground fault
  - Line – Line fault
  - Double Line – ground fault

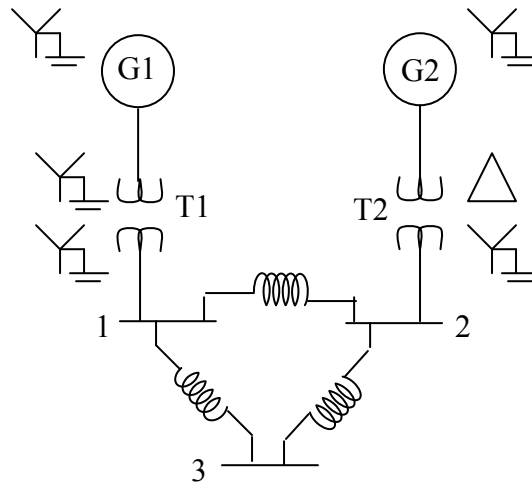






**EXERCISE:**

1. The one line diagram of a simple power system is shown in fig. The neutral of each generator is grounded through a current limiting reactor of  $0.25 / 3$  pu on a 100 MVA base. The system data expressed in pu on a common 100 MVA base is tabulated below. The generators are running on no-load at their rated voltage and rated frequency with their emfs in phase.



Determine the fault current for the following faults.

- A balanced three phase fault at bus 3 through a fault impedance  $Z_f = j 0.1$  pu.
- A single line to ground fault at bus 3 through a fault impedance  $Z_f = j0.10$  pu
- A line to line fault at bus 3 through a fault impedance  $Z_f = j0.1$  pu.
- A double line to ground fault at bus 3 through a fault impedance  $Z_f = j0.1$  pu

Item	Base MVA	Voltage Rating	$X^1$	$X^2$	$X^0$
G1	100	20 kV	0.15	0.15	0.05
G2	100	20 kV	0.15	0.15	0.05
T1	100	20 / 220 kV	0.10	0.10	0.10
T2	100	20 / 220 kV	0.10	0.10	0.10
L12	100	220 kV	0.125	0.125	0.30
L13	100	220 kV	0.15	0.15	0.35
L23	100	220 kV	0.25	0.25	0.7125



**RESULT:**

Thus, the fault currents during Symmetrical and Unsymmetrical faults were calculated for the given system and the results were verified using the “Power World Simulator”.

**REFERENCES:**

1. Hadi Saadat, ‘Power System Analysis’, Tata McGraw – Hill Publishing, Co. Ltd., New Delhi, 2002.
2. Elgerd, “Electric Energy System Theory” – An Introduction”, Tata Mc- Graw Hill publishing co.ltd, New Delhi 2003.

**THEORETICAL CALCULATIONS:**



Exp. No: 10

Date:

## **TRANSIENT STABILITY ANALYSIS OF SINGLE MACHINE CONNECTED TO INFINITE BUS**

### **AIM:**

To find the critical clearing time and the critical clearing angle of single machine system connected to infinite bus under the specified fault condition using MATLAB Simulink.

### **BASIC KNOWLEDGE REQUIRED:**

- Stability studies
- Power angle curves
- Swing curves

### **SOFTWARE REQUIRED:**

MATLAB 6.5

### **PROCEDURE:**

7. Double click the MATLAB icon.
8. Open a new model file,
9. Open the Simulink library from menu.
10. Click on the required components, drag and place one by one in new model file.
11. Connect them and enter the data to form the model of single machine system connected to infinite bus under the specified fault condition.
12. Save and run the model for different fault clearing time from a minimum value to find the critical clearing time and the critical clearing angle.



**NOMENCLATURE:**

$P_m$  = pu mechanical power

$P_e$  = pu electrical power

$E'$  = Constant voltage back of transient reactance in pu

$V$  = Infinite bus bar voltage in pu

$X_1$  = pu reactance between buses E & V before fault

$X_2$  = pu reactance between buses E & V during fault

$\delta$  = Power angle

$H$  = pu inertia constant

$f$  = System nominal frequency

$\omega$  = Angular frequency

$t$  = Fault clearing time

**FORMULAH:**

$$(i) \delta_{i+1}^c = \delta_i + \left( \frac{\frac{d\delta}{dt} \Big|_{\Delta\omega_i} + \frac{d\delta}{dt} \Big|_{\Delta\omega_i^p}}{2} \right) \Delta t$$

$$(ii) \frac{d\delta}{dt} \Big|_{\Delta\omega_i^p} = \Delta\omega_{i+1}^p = \Delta\omega_i + \frac{d\Delta\omega}{dt} \Big|_{\delta_i} \Delta t$$

$$(iii) \frac{d\Delta\omega}{dt} = \frac{\pi f_o}{H} (P_m - P_{2\max} \sin\delta)$$

$$(iv) P_{2\max} = \frac{|E'V|}{X_2}$$

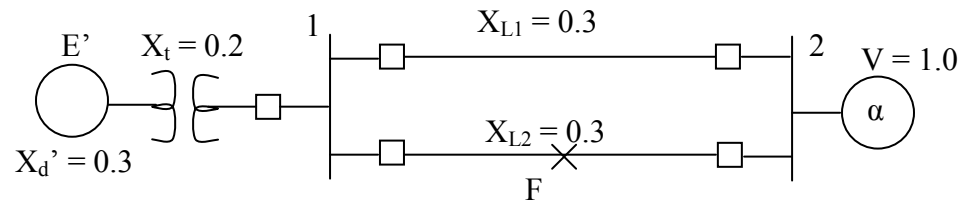
$$(v) \delta_o = \sin^{-1} \left( \frac{P_e}{P_{1\max}} \right) ; P_{1\max} = \frac{|E'V|}{X_1}$$

$$(vi) \Delta\omega_o = 0$$



**EXAMPLE PROBLEM:**

1. A 60 Hz synchronous generator having inertia constant  $H = 5$  MJ/MVA and a direct axis reactance  $X_d' = 0.3$  pu is connected to an infinite bus through a purely reactive circuit as shown in Fig. reactances are marked on the diagram on a common scale. The generator is delivering real power  $P_e = 0.8$  pu and  $Q = 0.074$  pu to the infinite bus at a voltage of  $V = 1$  pu.



If a three phase fault at the middle of one line is cleared by isolating the faulted circuit. Determine the critical clearing time and the critical clearing angle

**RESULT:**

Thus, the critical clearing time and the critical clearing angle of single machine system connected to infinite bus were found by using MATLAB Simulink.

**REFERENCES:**

1. Hadi Saadat, 'Power System Analysis', Tata McGraw – Hill Publishing, Co. Ltd., New Delhi, 2002.
2. C.L.Wadhwa, "Electrical power systems", new age international (P) limited, publishers, Second Edition, 1998.
3. Modern Power system analysis – I.J.Nagrath & D.P.Kothari

**THEORETICAL CALCULATIONS:**

Exp. No: 11

Date:

## **TRANSIENT STABILITY ANALYSIS OF MULTI MACHINE SYSTEMS**

### **AIM:**

To find critical clearing time and transient stability limit of multi machine systems under specified fault condition using “MiPower” software package.

### **BASIC KNOWLEDGE REQUIRED:**

- Stability studies
- Power angle curves
- Swing curves

### **SOFTWARE REQUIRED:**

- MiPower 4.0

### **STEPS TO BE FOLLOWED:-**

- vii. Open power system Network Editor in MiPower.
- viii. Configure the database
- ix. Draw the elements of single line diagram from the available blocks and enter the data simultaneously.
- x. Solve for load flow analysis.
- xi. Keeping the results of load flow analysis as initial condition, solve for transient stability by simulating the list of disturbances.
- xii. Change the fault clearing time and find the critical clearing time by trial and error method.
- xiii. Change the scheduled power and find the transient stability limit of the system by trial and error method.



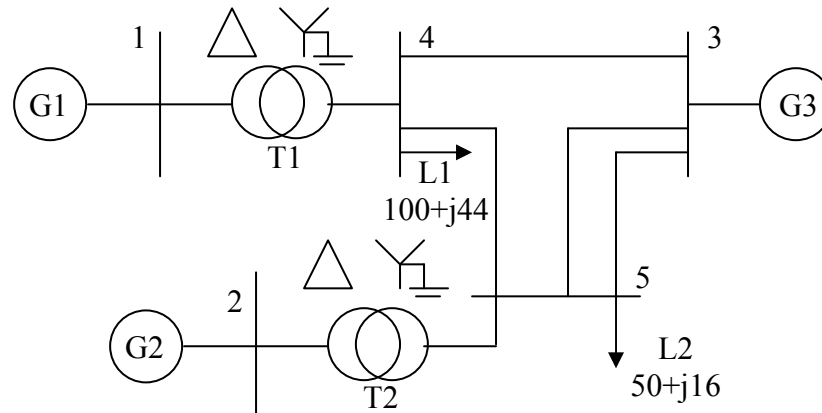






**EXERCISE:**

1. Fig. shows a single line diagram of a 5 bus system with three generating units, four lines and two transformers and two loads. Per unit transmission line series impedances and shunt susceptances are given on 100 MVA base, generator's transient impedances and transformers leakage reactances are given in the accompanying table.



Values are given on 100 MVA base. Frequency = 60 Hz.

If a 3 phase fault occurs on line 4 -5 near bus 4 and fault is cleared by simultaneously opening the circuit breaker at the ends of the line 4 -5 at 0.225 sec (fault clearing time), plot the swing curve and comment on stability of machine 1 and machine 2.

Transmission Line Details		
Bus code	Impedance	Line charging
p -q	$Z_{pq}$	$Y'_{pq}/2$
3 - 4	$0.007 + j0.04$	$j0.041$
3 - 5 (1)	$0.008 + j0.047$	$j0.049$
3 - 5 (2)	$0.008 + j0.047$	$j0.049$
4 - 5	$0.018 + j0.110$	$j0.113$

**Transformer Details:**

T1 = 20/230 kV, 400 MVA with leakage reactance = 0.022 pu

T2 = 18/230 kV, 250 MVA with leakage reactance = 0.040 pu

**Generator Details:**

G1 = 400 MVA, 20 kV,  $X_d' = 0.067$  pu,  $H = 11.2$  MJ/MVA

G2 = 250 MVA, 18 kV,  $X_d' = 0.10$  pu,  $H = 8.0$  MJ/MVA

G3 = 1000 MVA, 230 kV,  $X_d' = 0.00001$  pu,  $H = 1000$  MJ/MVA (Infinite bus modeling)



<b>Generation and Load Details</b>					
<b>Bus Code 'p'</b>	<b>Generation</b>		<b>Load</b>		<b>Specified Voltage</b>
	<b>MW</b>	<b>Mvar</b>	<b>MW</b>	<b>Mvar</b>	
1	350	71.2	0	0	1.03
2	185	29.8	0	0	1.02
3	800	0	0	0	1.0
4	0	0	100	44	Unknown
5	0	0	50	16	Unknown

### **RESULT:**

Thus, the critical clearing time and the transient stability limit of multi machine systems were studied and the results were verified using MiPower.

### **REFERENCES:**

1. Hadi Saadat, 'Power System Analysis', Tata McGraw – Hill Publishing, Co. Ltd., New Delhi, 2002.
2. C.L.Wadhwa, "Electrical power systems", new age international (P) limited, publishers, Second Edition, 1998.
3. Modern Power system analysis – I.J.Nagrath & D.P.Kothari.