DHANALAKSHMI COLLEGE OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

EE 1404 – POWER SYSTEM SIMULATION LABORATORY

LAB MANUAL/ OBSERVATION

2009 – 2010 ODD SEMESTER

NAME :

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Asst.Professor /EEE

LIST OF EXPERIMENTS

1. **COMPUTATION OF PARAMETERS AND MODELLINGOF TRANSMISSION LINES.**

2. **FORMATION OF ADMITTANCE MATRICES.**

3. **FORMATION OF IMPEDANCE MATRICES.**

4. **SOLUTION OF POWER FLOW USING GAUSS-SEIDEL METHOD.**

5. **SHORT CIRCUIT ANALYSIS.**

6. **SOLUTION OF POWER FLOW USING NEWTON-RAPHSON METHOD.**

7. **LOAD – FREQUENCY DYNAMICS OF SINGLE AREA POWER SYSTEMS.**

8. **LOAD – FREQUENCY DYNAMICS OF TWO AREA POWER SYSTEMS.**

9. **TRANSIENT AND SMALL SIGNAL STABILITY ANALYSIS – SINGLE MACHINE INFINITE BUS SYSTEM.**

10. **ECONOMIC DISPATCH IN POWER SYSTEMS**

I CYCLE

1. COMPUTATION OF PARAMETERS AND MODELLINGOF TRANSMISSION LINES.

2. FORMATION OF ADMITTANCE MATRICES.

3. FORMATION OF IMPEDANCE MATRICES.

4. SOLUTION OF POWER FLOW USING GAUSS-SEIDEL METHOD.

5. SHORT CIRCUIT ANALYSIS.

II CYCLE

6. SOLUTION OF POWER FLOW USING NEWTON-RAPHSON METHOD.

7. LOAD – FREQUENCY DYNAMICS OF SINGLE AREA POWER SYSTEMS.

8. LOAD – FREQUENCY DYNAMICS OF TWO AREA POWER SYSTEMS.

9. TRANSIENT AND SMALL SIGNAL STABILITY ANALYSIS – SINGLE MACHINE INFINITE BUS SYSTEM.

10. ECONOMIC DISPATCH IN POWER SYSTEMS

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COMPUTATION OF PARAMETERS AND MODELLING OF TRANSMISSION LINES

Expt.No :
Date :

AIM :

(i) To determine the positive sequence line parameters L and C per phase per kilometre of a three phase single and double circuit transmission lines for different conductor arrangements.

(ii) To understand modeling and performance of medium lines.

SOFTWARE REQUIRED: MATLAB 5.3

THEORY :

Transmission line has four parameters – resistance, inductance, capacitance and conductance. The inductance and capacitance are due to the effect of magnetic and electric fields around the conductor. The resistance of the conductor is best determined from the manufactures data, the inductances and capacitances can be evaluated using the formula.

Inductance:

The general formula:

$$L = 0.2 \ln (D_m / D_s)$$

Where,

D_m = geometric mean distance (GMD)

D_s = geometric mean radius (GMR)

I. Single phase 2 wire system

GMD = D

GMR = $re^{-1/4} = r'$

Where, r = radius of conductor

II. Three phase – symmetrical spacing

GMD = D

GMR = $re^{-1/4} = r'$

Where, r = radius of conductor

III. Three phase – Asymmetrical Transposed

GMD = geometric mean of the three distance of the symmetrically place conductors

$= \sqrt[3]{D_{AB}D_{BC}D_{CA}}$

$GMR = re^{-1/4} = r'$

Where, r = radius of conductors

Composite conductor lines

The inductance of composite conductor X., is given by

$L_x = 0.2 \ln (GMD/GMR)$

where,

$GMD = \sqrt[mn]{(D_{aa'} D_{ab'})\ldots\ldots(D_{na'}\ldots\ldots D_{nm'})}$

$GMR = \sqrt[n^2]{(D_{aa} D_{ab}\ldots\ldots D_{an})\ldots\ldots(D_{na} D_{nb}\ldots\ldots D_{nn})}$

where, $r'_a = r_a e^{(-1/4)}$

Bundle Conductors:

The GMR of bundle conductor is normally calculated

GMR for two sub conductor $c = (D_s * d)^{1/2}$

GMR for three sub conductor $D_s^b = (D_s * d^2)^{1/3}$

GMR for four sub conductor $D_s^b = 1.09 (D_s * d^3)^{1/4}$

where, D_s is the GMR of each subconductor and d is bundle spacing

Three phase – Double circuit transposed:

The inductance per phase in milli henries per km is

$L = 0.2 \ln (GMD / GMR_L)$ mH/km

where,

GMR_L is equivalent geometric mean radius and is given by

$GMR_L = (D_{SA} D_{SB} D_{SC})^{1/3}$

where,

$D_{SA} D_{SB}$ and D_{SC} are GMR of each phase group and given by

$D_{SA} = \sqrt[4]{(D_s^b D_{a1a2})^2} = [D_s^b D_{a1a2}]^{1/2}$

$D_{SB} = \sqrt[4]{(D_s^b D_{b1b2})^2} = [D_{sb} D_{b1b2}]^{1/2}$

$D_{SC} = \sqrt[4]{(D_s^b D_{c1c2})^2} = [D_{sb} D_{c1c2}]^{1/2}$

where,

D_s^b =GMR of bundle conductor if conductor $a_1, a_2\ldots$.. are bundle conductor.

$D_s^b = r_{a1}' = r_{b1} = r_{a'2} = r_{b'2} = r_{c'2}$ if $a_1, a_2\ldots\ldots$ are bundle conductor

GMD is the equivalent GMD per phase" & is given by

$GMD = [D_{AB} * D_{BC} * D_{CA}]^{1/3}$

where,

D_{AB}, D_{BC}&D_{CA} are GMD between each phase group A-B, B-C, C-A which are given by

$D_{AB} = [D_{a1b1} * D_{a1b2} * D_{a2b1} * D_{a2b2}]^{1/4}$

$D_{BC} = [D_{b1c1} * D_{b1c2} * D_{b2c1} * D_{b2c2}]^{1/4}$

$D_{CA} = [D_{c1a1} * D_{c2a1} * D_{c2a1} * D_{c2a2}]^{1/4}$

Capacitance

A general formula for evaluating capacitance per phase in micro farad per km of a transmission line is given by

$C = 0.0556/ \ln (GMD/GMR)$ μF/km

Where,

GMD is the "Geometric mean distance" which is same as that defined for inductance under various cases.

PROCEDURE:

1. Enter the command window of the MATLAB.
2. Create a new M – file by selecting File - New – M – File
3. Type and save the program in the editor window.
4. Execute the program by either pressing Tools – Run.
5. View the results.

EXERCISES:

1 A three-phase transposed line composed of one ACSR, 1,43,000 cmil, 47/7 Bobolink conductor per phase with flat horizontal spacing of 11m between phases a and b and between phases b and c. The conductors have a diameter of 3.625 cm and a GMR of 1.439 cm. The line is to be replaced by a three-conductor bundle of ACSR 477,000-cmil, 26/7 Hawk conductors having the same cross sectional area of aluminum as the single-conductor line. The conductors have a diameter of 2.1793 cm and a GMR of 0.8839 cm. The new line will also have a flat horizontal configuration, but it is to be operated at a higher voltage and therefore the phase spacing is increased to 14m as measured from the center of the bundles. The spacing between the conductors in the bundle is 45 cm.

(a) Determine the inductance and capacitance per phase per kilometer of the above two lines.

(b) Verify the results using the MATLAB program.

PROGRAM :

```
[GMD, GMRL, GMRC] = gmd;
L = 0.2*log(GMD/GMRL)
C = 0.0556/log(GMD/GMRC)
```

MANUAL CALCULATIONS :

2. A three phase overhead line 200km long R = 0.16 ohm/km and Conductor diameter of 2cm with spacing 4,5,6m transposed.Find A,B,C,D constants ,sending end voltage,current ,power factor and power when the line is delivering full load of 50MW at 132kV ,0.8 pf lagging , transmission efficiency , receiving end voltage and regulation.

PROGRAM :

```
ab=input('value of ab');
bc=input('value of bc');
ca=input('value of ca');
pr=input('receving end power in mw');
vr=input('receving end voltage in kv');
pfr=input('receving end powerfactor');
l=input('length of the line in km');
r=input('resistance/ph/km');
f=input('frequency');
D=input('diameter in m');
rad=D/2;
newrad=(0.7788*rad);
deq=(ab*bc*ca)^(1/3);
L=2*10^(-7)*log(deq/newrad);
C=(2*pi*8.854*10^-12)/log(deq/rad);
XL=2*pi*f*L*l*1000;
rnew=r*l;
Z=rnew+i*(XL);
Y=i*(2*pi*f*C*l*1000);
A=1+((Y*Z)/2);
D=A;
B=Z;
C=Y*(1+(Y*Z)/4);
vrph=(vr*10^3)/1.732;
irold=(pr*10^6)/(1.732*vr*10^3*.8);
k=sin(acos(pfr));
ir=irold*(pfr-(j*k));
vs=((A*vrph)+(B*ir));
is=((C*vrph)+(D*ir));
angle(vs);
angle(is);
f=angle(vs);
u=angle(is);
PFS=cos(f-u);
eff=((pr*10^6)/(3*abs(vs)*abs(is)*PFS))*100;
reg=(((abs(vs)/abs(A))-abs(vrph))/abs(vrph))*100;
L
C
rnew
A
B
C
abs(vs)
abs(is)
angle(vs)*180/pi
angle(is)*180/pi
PFS
eff
reg
```

MANUAL CALCULATIONS:

RESULT :

FORMATION OF BUS ADMITTANCE MATRICES

Expt.No :
Date :

AIM:

To determine the admittance matrices for the given power system network.

SOFTWARE REQUIRED: MATLAB

THEORY:

Bus admittance is often used in power system studies. In most of the power system studies it is required to form y- bus matrix of the system by considering certain power system parameters depending upon the type of analysis.

Y-bus may be formed by inspection method only if there is no mutual coupling between the lines. Every transmission line should be represented by π- equivalent. Shunt impedances are added to diagonal element corresponding to the buses at which these are connected. The off diagonal elements are unaffected. The equivalent circuit of Tap changing transformers is included while forming Y-bus matrix.

FORMATION OF Y-BUS MATRIX

$$\text{Generalised Y-bus} = \begin{bmatrix} y_{ii} \ldots\ldots\ldots\ldots y_{id} \\ y_{di} \ldots\ldots\ldots y_{dd} \end{bmatrix}$$

where, Y_{ii} = Self admittance
Y_{di} = Transfer admittance

PROCEDURE:

1. Enter the command window of the MATLAB.
2. Create a new M – file by selecting File - New – M – File
3. Type and save the program in the editor window.
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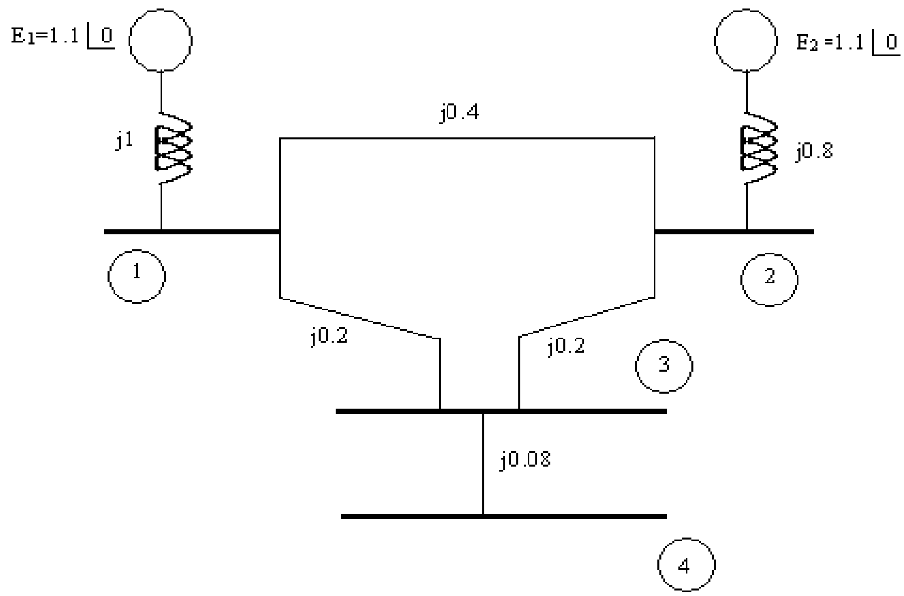
5. View the results.

I. EXERCISE:

(i) Determine the Y bus matrix and Z bus matrix for the power system network shown in fig.
(ii) Check the results obtained in using MATLAB.



PROGRAM :

```
z = [0  1  0  1.0
    0  2  0  0.8
    1  2  0  0.4
    1  3  0  0.2
    2  3  0  0.2
    3  4  0  0.08];
  Y = ybus(z)
```

MANUAL CALCULATIONS:

RESULT:

FORMATION OF BUS IMPEDANCE MATRICES

Expt.No:
Date :

AIM :

To determine the bus impedance matrices for the given power system network.

SOFTWARE REQUIRED: MATLAB 5.3

THEORY:

FORMATION OF Z-BUS MATRIX

In bus impedance matrix the elements on the main diagonal are called driving point impedance and the off-diagonal elements are called the transfer impedance of the buses or nodes. The bus impedance matrix are very useful in fault analysis.

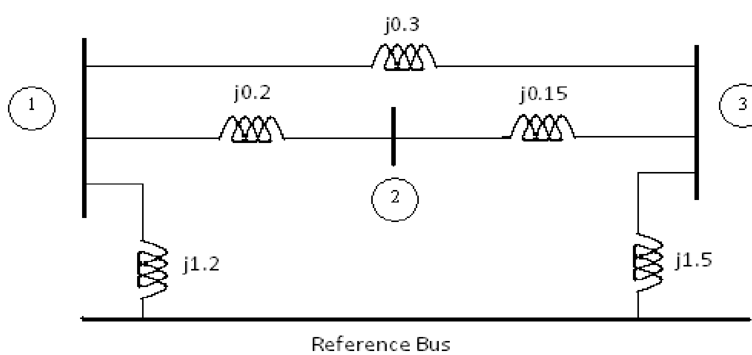
The bus impedance matrix can be determined by two methods. In one method we can form the bus admittance matrix and than taking its inverse to get the bus impedance matrix. In another method the bus impedance matrix can be directly formed from the reactance diagram and this method requires the knowledge of the modifications of existing bus impedance matrix due to addition of new bus or addition of a new line (or impedance) between existing buses.

PROCEDURE:

1. Enter the command window of the MATLAB.
2. Create a new M – file by selecting File - New – M – File
3. Type and save the program in the editor Window
4. Execute the program by either pressing Tools – Run.
5. View the results.

EXERCISE:

(i) Determine the and Z bus matrix for the power system network shown in fig.
(ii) Check the results obtained in using MATLAB.



PROGRAM :

```
z = [0  1  0  1.0
     0  2  0  0.8
     1  2  0  0.4
     1  3  0  0.2
     2  3  0  0.2
     3  4  0  0.08];
  Y = ybus(z)
  Ibus = [-j*1.1; -j*1.25; 0; 0];
  Zbus = inv(Y)
  Vbus = Zbus*Ibus
```

MANUAL CALCULATIONS:

RESULT:

SOLUTION OF POWER FLOW USING GAUSS-SEIDEL METHOD

Expt.No :
Date :

AIM :

To understand, in particular, the mathematical formulation of power flow model in complex form and a simple method of solving power flow problems of small sized system using Gauss-Seidel iterative algorithm

SOFTWARE REQUIRED: MATLAB 5.3

THEORY:

The GAUSS – SEIDEL method is an iterative algorithm for solving a set of non-linear load flow equations.

The non-linear load flow equation is given by

$$V_p^{k+1} = \frac{1}{Y_{pp}}\left[\frac{P_p - j\,Q_p}{(V_p^k)^*} - \sum_{q=1}^{p-1} Y_{pq} V_q^{k+1} - \sum_{q=p+1}^{n} V_q^k\right]$$

The reactive power of bus-p is given by

$$Q_P^{k+1} = (-1) \times \mathrm{Im}\left[(V_p^k)^* \left[\sum_{q=1}^{p-1} Y_{pq} V_q^{k+1} + \sum_{q=p}^{n} Y_{pq} V_q^k\right]\right]$$

PROCEDURE:

1. Enter the command window of the MATLAB.
2. Create a new M – file by selecting File - New – M – File
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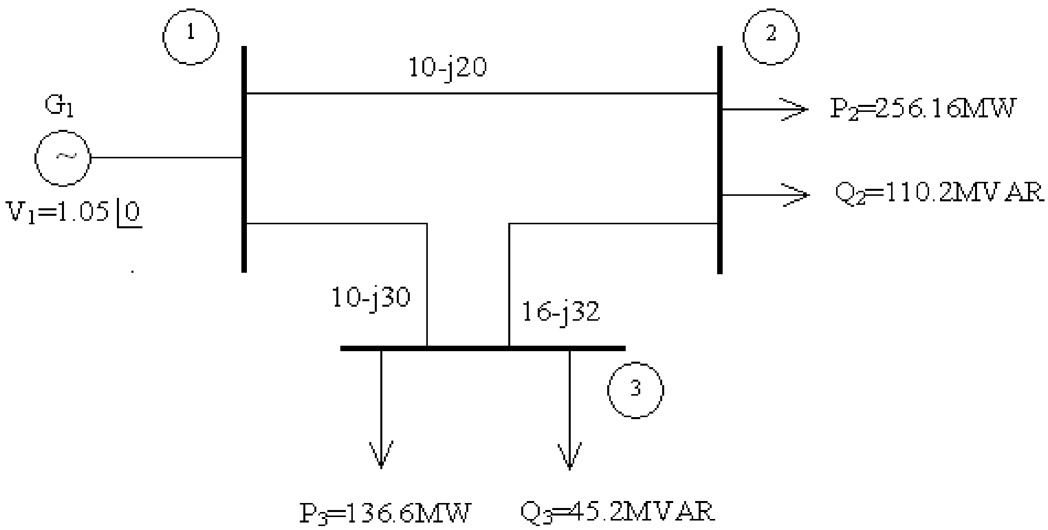
4. Execute the program by either pressing Tools – Run.
5. View the results.

EXERCISE :

The figure shows the single line diagram of a simple 3 buses power system with generator at bus 1.The magnitude at bus 1 is adjusted to 1.05pu. The scheduled loads at buses 2 and 3 are marked on the diagram. Line impedance are marked in pu. The base value is 100kVA. The line charging susceptances are neglected. Determine the phasor values of the voltage at the load buses 2 and 3. Find the slack bus real and reactive power.

Verify the result using MATLAB.



Program

```
%Gauss Sedial
clc;
data=[1 1 2 10-j*20
  2 1 3 10-j*30
  3 2 3  16-j*32]
elements=max(data(:,1));
bus=max(max(data(:,2)),max(data(:,3)));
y=zeros(bus,bus);
for p=1:bus,
  for q=1:elements,
    if(data(q,2)==p|data(q,3)==p)
      y(p,p)=y(p,p)+data(q,4);
    end
  end
end
```

```
for p=1:bus,
  for q=1:bus,
    if (p~=q)
      for r=1:elements
        if((data(r,2)==p&data(r,3)==q)|(data(r,2)==q&data(r,3)==p))
          y(p,q)=-(data(r,4));
        end
      end
    end
  end
end
a1=input('enter p2 in MW:');
b1=input('enter q2 in MVAR:');
a2=input('enter p3 in MW:');
b2=input('enter q3 in MVAR');
pu=input('enter the base value in MVA');
p2=(a1/pu);
q2=(b1/pu);
p3=(a2/pu);
q3=(b2/pu);
dx1=1+j*0;
dx2=1+j*0;
v1=1.05;
v2=1+j*0;
v3=1+j*0;
iter=0;
disp('iter v2 v3');
while(abs(dx1)&abs(dx2)>=0.00001)&iter<7;
  iter=iter+1;
  g1=(((p2-j*q2)/conj(v2))+(-y(1,2)*v1)+(-y(2,3)*v3))/y(2,2);
  g2=(((p3-j*q3)/conj(v3))+(-y(1,3)*v1)+(-y(2,3)*g1))/y(3,3);
  dx1=g1-v2;
  dx2=g2-v3;
  v2=v2+dx1;
  v3=v3+dx2;
  fprintf ('%g',iter),disp([v2,v3]);
  end
```

MANUAL CALCULATION

RESULT

SOLUTION OF POWER FLOW USING NEWTON-RAPHSON METHOD

Expt.No :
Date :

AIM :

To determine the power flow analysis using Newton – Raphson method

SOFTWARE REQUIRED : MATLAB

THEORY :

The Newton Raphson method of load flow analysis is an iterative method which approximates the set of non-linear simultaneous equations to a set of linear simultaneous equations using Taylor's series expansion and the terms are limited to first order approximation.

The load flow equations for Newton Raphson method are non-linear equations in terms of real and imaginary part of bus voltages.

$$P_P = \sum_{q=1}^{n} \{ e_p(e_q G_{pq} + f_q B_{pq}) + f_p (f_q G_{pq} - e_q B_{pq}) \}$$

$$Q_P = \sum_{q=1}^{n} \{ f_p (e_q G_{pq} + f_q B_{pq}) - e_p (f_q G_{pq} - e_q B_{pq}) \}$$

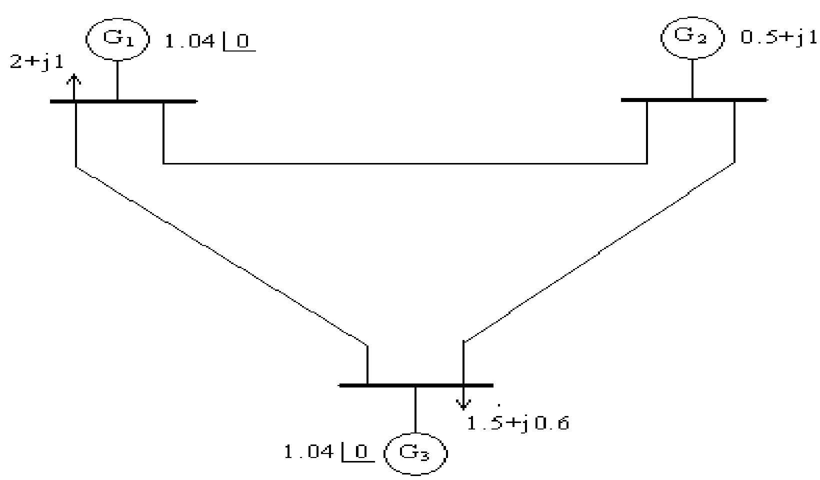
$$|V_p|^2 = e_p^2 + f_p^2$$

where, e_p = Real part of V_p

f_p = Imaginary part of V_p

G_{pq}, B_{pq} = Conductance and Susceptance of admittance Y_{pq} respectively.

EXERCISE



1. Consider the 3 bus system each of the 3 line bus a series impedance of 0.02 + j0.08 p.u and a total shunt admittance of j0.02 pu. The specified quantities at the buses are given below :

Bus	Real load demand, P_D	Reactive Load demand, Q_D	Real power generation,P_G	Reactive Power Generation, Q_G	Voltage Specified
1	2	1	-	-	V_1=1.04
2	0	0	0.5	1	Unspecified
3	1.5	0.6	0	Q_{G3} = ?	V_3 = 1.04

2. Verify the result using MATLAB

PROGRAM :

```
%NEWTON RAPHSON METHOD
clc;
gbus = [1 2.0 1.0 0.0 0.0
   2 0.0 0.0 0.5 1.0
   3 1.5 0.6 0.0 0.0];
ybus = [5.882-j*23.528 -2.941+j*11.764 -2.941+j*11.764
       -2.941+j*11.764  5.882-j*23.528 -2.941+j*11.764
       -2.941+j*11.764 -2.941+j*11.764  5.882-j*23.528];
    t= 0.001
    v1=1.04+j*0;
    v2=1+j*0;
    v3=1.04+j*0;
    del3=angle(v3);
    del1=angle(v1);
    del2=angle(v2);
    %abs(ybus(2,1))
    %abs(v2)
    for i=1:10
       p2=(abs(v2)*abs(v1)*abs(ybus(2,1))*cos((angle(ybus(2,1)))+del1-
del2))+abs(v2)*
       abs(v2)*abs(ybus(2,2))*cos((angle(ybus(2,2))))+(abs(v2)*abs(v3)*
       abs(ybus(2,3))*cos((angle(ybus(2,3))+del3-del2));
       q2=-(abs(v2)*abs(v1)*abs(ybus(2,1))*sin((angle(ybus(2,1)))+del1-del2))-
       abs(v2)*abs(v2)*abs(ybus(2,2))*sin((angle(ybus(2,2))))-(abs(v2)*abs(v3)*
       abs(ybus(2,3))*sin((angle(ybus(2,3)))+del3-del2));
       p3=(abs(v3)*abs(v1)*abs(ybus(3,1))*cos((angle(ybus(3,1)))+del1-

del3))+abs(v3)*abs(v3)*abs(ybus(3,3))*cos((angle(ybus(3,3))))+(abs(v2)*abs(v3)*
       abs(ybus(3,2))*cos((angle(ybus(3,2)))+del2-del3));
       delp20=gbus(2,4)-gbus(2,2)-p2;
       delp30=gbus(3,4)-gbus(3,2)-p3;
       delq20=gbus(2,5)-gbus(2,3)-q2;
       J(1,1)=(abs(v2)*abs(v1)*abs(ybus(2,1))*sin((angle(ybus(2,1)))+del1-
       del2))+(abs(v2)*abs(v3)*abs(ybus(2,3))*sin((angle(ybus(2,3)))+del3-
del2));
       J(1,2)=-(abs(v2)*abs(v3)*abs(ybus(2,3))*sin((angle(ybus(2,3)))+del3-
del2));
       J(1,3)=(abs(v1)*abs(ybus(2,1))*cos((angle(ybus(2,1)))+del1-
```

```
del2))+2*(abs(v2)*abs(ybus(2,2))*cos((angle(ybus(2,2))))+(abs(v3)*abs(ybus(2,3))*
       cos((angle(ybus(2,3)))+del3-del2));
       J(2,1)=-(abs(v3)*abs(v2)*abs(ybus(3,2))*sin((angle(ybus(3,2)))+del2-
del3));
       J(2,2)=(abs(v3)*abs(v1)*abs(ybus(3,1))*sin((angle(ybus(3,1)))+del1-
       del3))+(abs(v3)*abs(v2)*abs(ybus(3,2))*sin((angle(ybus(3,2)))+del2-
del3));
       J(2,3)=(abs(v3)*abs(ybus(3,2))*cos((angle(ybus(3,2)))+del2-del3));
       J(3,1)=(abs(v2)*abs(v1)*abs(ybus(2,1))*cos((angle(ybus(2,1)))+del1-
       del2))-(abs(v2)*abs(v3)*abs(ybus(2,3))*cos((angle(ybus(2,3)))+del2-
del3));
       J(3,2)=(abs(v2)*abs(v3)*abs(ybus(2,3))*cos((angle(ybus(2,3)))+del2-
del3));
       J(3,3)=-(abs(v2)*abs(ybus(2,1))*sin((angle(ybus(2,1)))+del1-
       del2))-2*(abs(v2)*abs(ybus(2,2))*sin((angle(ybus(2,2))))-
(abs(v3)*abs(ybus(2,3))*
       sin((angle(ybus(2,3)))+del3-del2));
    end
    J
    inv(J);
    A=[del2;del3;abs(v2)];
    delA0=[delp20;delp30;delq20];
    delA1=inv(J)*delA0;
    delA1;
    b0=abs(v2);
    A1=[del2;del3;b0]+delA1;
    A1-delA0;
    if((A1-delA0)<=t)
       break;
       del2=A1(1,1);
       del3=A1(2,1);
       abs(v2)=A1(3,1);
    end
    A1
```

MANUAL CALCULATIONS :

RESULT:

SHORT CIRCUIT ANALYSIS

Expt.No :
Date :
AIM :

To become familiar with modelling and analysis of power systems under faulted condition and to compute the fault level, post-fault voltages and currents for different types of faults, both symmetric and unsymmetric.

PROGRAM REQUIRED: MATLAB 5.3

THEORY :

Symmetrical Fault :

II. Three phase fault :

From the thevenin's equivalent circuit

$$\text{Fault current } I_f'' = \frac{V_{th}}{Z_{th}}$$

Where V_{th} = Thevenin's Voltage
Z_{th} = Thevenin's Impedance

Unsymmetrical Fault :
Single line to ground fault :

$$\text{Fault current } I_f = I_a = 3I_{a1}$$

$$I_{a1} = \left[\frac{Ea}{Z_1+Z_2+Z_0} \right]$$

Line to line fault:

$$\text{Fault current } I_f = I_{a1}(a^2 - a)$$

$$I_{a1} = \frac{E_a}{Z_1+Z_2}$$

Double Line to ground fault :

$$\text{Fault current } I_f = 2 I_{a0} + (I_{a1} + I_{a2})(a^2 + a)$$

$$I_{a1} = \frac{E_a}{\left(Z_1 + \quad Z_0Z_2 \right)}$$

$$Z_0 + Z_2$$

$$I_{a2} = (- I_{a1}) * \frac{Z_0}{Z_0 + Z_2}$$

$$I_{a0} = -(I_{a1} - I_{a2})$$

Fault MVA = $\sqrt{3} * I_f * V_{pu}$

where, I_{a1}, I_{a2} and I_{a0} are positive, negative and zero phase sequence currents

Z_1, Z_2 and Z_o are positive, negative and zero phase sequence impedances

PROCEDURE:

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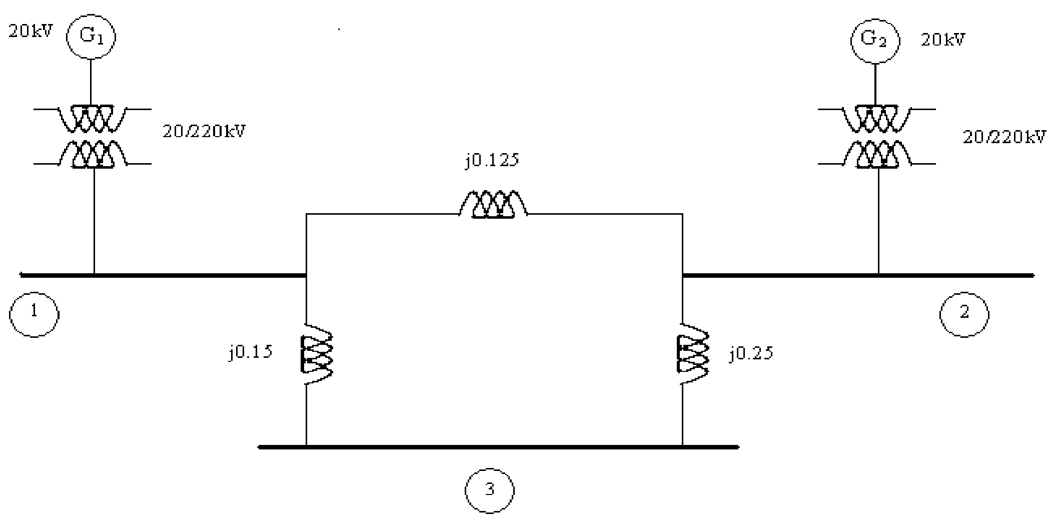
3. Type and save the program.
4. Execute the program by either pressing Tools – Run.

   View the results.

EXERCISE :



The one line diagram of a simple power system is shown in figure. The neutral of each generator is grounded through a current limiting reactor of 0.25/3 per unit on a 100MVA base. The system data expressed in per unit 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) A balanced three phase fault at bus 3 through a fault impedance Z_f = j0.1 per unit.

(b) A single line to ground fault at bus3 through a fault impedance Z_f = j0.1 per unit.

(c) A line to line fault at bus3 through a fault impedance Z_f = j0.1 per unit.

(d) A double line to ground fault at bus3 through a fault impedance Z_f = j0.1 per unit.

Item	Base MVA	Voltage Rating kV	X^1	X^2	X^0
G_1	100	20	0.15	0.15	0.05
G_2	100	20	0.15	0.15	0.05
T_1	100	20/220	0.10	0.10	0.10
T_2	100	20/220	0.10	0.10	0.10
L_{12}	100	220	0.125	0.125	0.30
L_{13}	100	220	0.15	0.15	0.35
L_{23}	100	220	0.25	0.25	0.7125

Verify the result using MATLAB program.

PROGRAM :

```
zdata1 = [0 1  0  0.25
         0 2  0  0.25
          1 2  0  0.125
          1 3  0  0.15
          2 3  0  0.25];

zdata0 = [0 1  0  0.40
        0 2  0  0.10
          1 2  0  0.30
          1 3  0  0.35
          2 3  0  0.7125];
zdata2 = zdata1;
Zbus1  = zbuild(zdata1)
Zbus0  = zbuild(zdata0)
Zbus2 = Zbus1;
symfault(zdata1,Zbus1)
lgfault(zdata0, Zbus0, zdata1, Zbus1, zdata2, Zbus2)
llfault(zdata1, Zbus1, zdata2, Zbus2)
dlgfault(zdata0, Zbus0, zdata1, Zbus1, zdata2, Zbus2)
```

MANUAL CALCULATIONS:

RESULT

LOAD – FREQUENCY DYNAMICS OF SINGLE AREA POWER SYSTEMS

Expt . No :

Date :

AIM :

To become familiar with modelling and analysis of the frequency and tie-line flow dynamics of a power system without and with load frequency controllers (LFC) and to design better controllers for getting better responses.

THEORY :

Active power control is one of the important control actions to be perform to be normal operation of the system to match the system generation with the continuously changing system load in order to maintain the constancy of system frequency to a fine tolerance level. This is one of the foremost requirements in proving quality power supply. A change in system load cases a change in the speed of all rotating masses (Turbine – generator rotor systems) of the system leading to change in system frequency. The speed change form synchronous speed initiates the governor control (primary control) action result in all the participating generator – turbine units taking up the change in load, stabilizing system frequency. Restoration of frequency to nominal value requires secondary control action which adjust the load - reference set points of selected (regulating) generator – turbine units. The primary objectives of automatic generation control (AGC) are to regulate system frequency to the set nominal value and also to regulate the net interchange of each areas to the scheduled value by adjusting the outputs of the regulating units. This function is referred to as load – frequency control(LFC).

PROCEDURE :

1. Enter the command window of the MATLAB.
2. Create a new Model by selecting File - New – Model
3. Pick up the blocks from the simulink library browser and form a block diagram.
4. After forming the block diagram , save the block diagram.
5. Double click the scope and view the result.

EXERCISE:

1.An isolated power station has the following parameters

Turbine time constant τ_T = 0.5sec

Governor time constant τ_g = 0.2sec

Generator inertia constant H = 5sec

Governor speed regulation = R per unit

The load varies by 0.8 percent for a 1 percent change in frequency , i.e,D = 0.8

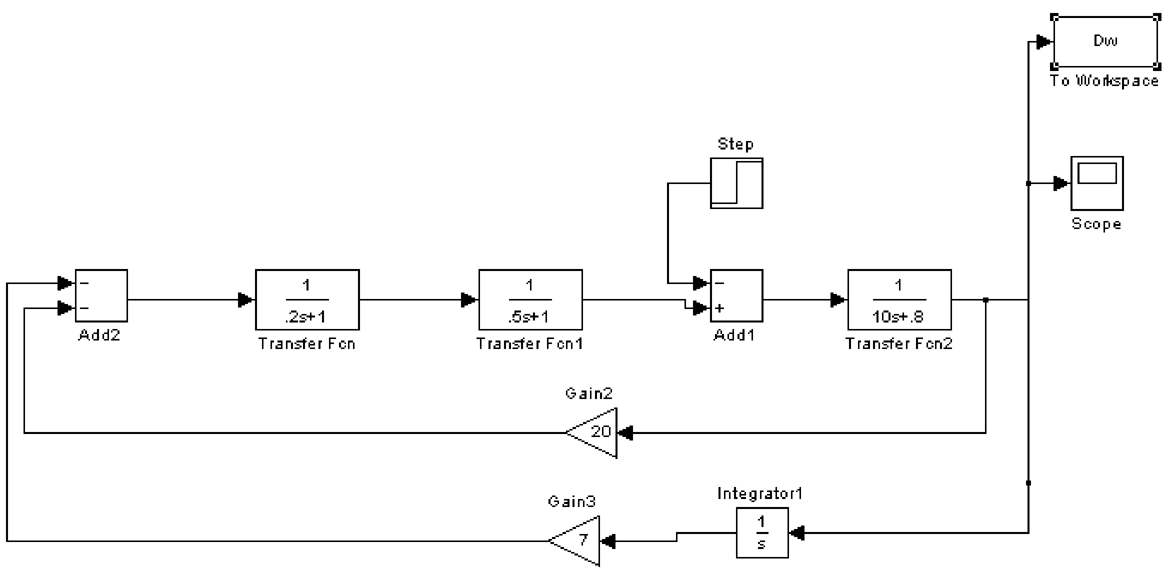
(a) Use the Routh – Hurwitz array to find the range of R for control system stability.

(b) Use MATLAB to obtain the root locus plot.

(c) The governor speed regulation is set to R = 0.05 per unit.The turbine rated output is 250MW at nominal frequency of 60Hz. A sudden load change of 50MW(ΔP_L = 0.2 per unit) occurs.

(i) Find the steady state frequency deviation in Hz.

(ii) Use MATLAB to obtain the time domain performance specifications and the frequency deviation step response.



MANUAL CALCULATIONS:

RESULT:

LOAD – FREQUENCY DYNAMICS OF TWO AREA POWER SYSTEMS

Expt . No :

Date :

AIM :

To become familiar with modelling and analysis of the frequency and tie-line flow dynamics of a two area power system without and with load frequency controllers (LFC) and to design better controllers for getting better responses.

THEORY:

Active power control is one of the important control actions to be perform to be normal operation of the system to match the system generation with the continuously changing system load in order to maintain the constancy of system frequency to a fine tolerance level. This is one of the foremost requirements in proving quality power supply. A change in system load cases a change in the speed of all rotating masses (Turbine – generator rotor systems) of the system leading to change in system frequency. The speed change form synchronous speed initiates the governor control (primary control) action result in all the participating generator – turbine units taking up the change in load, stabilizing system frequency. Restoration of frequency to nominal value requires secondary control action which adjust the load - reference set points of selected (regulating) generator – turbine units. The primary objectives of automatic generation control (AGC) are to regulate system frequency to the set nominal value and also to regulate the net interchange of each areas to the scheduled value by adjusting the outputs of the regulating units. This function is referred to as load – frequency control(LFC).

PROCEDURE:

1. Enter the command window of the MATLAB.
2. Create a new Model by selecting File - New – Model
3. Pick up the blocks from the simulink library browser and form a block diagram.
4. After forming the block diagram , save the block diagram.
5. Double click the scope and view the result.

EXERCISE :

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

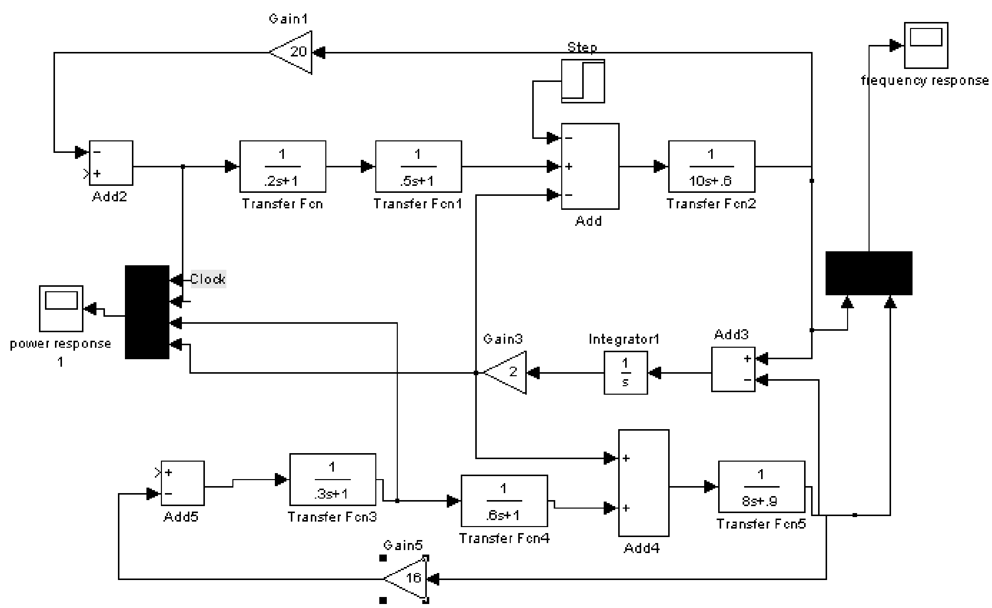
Area	1	2
Speed Regulation	R_1=0.05	R_2=0.0625
Frequency –sens.load coeff.	D_1=0.6	D_2=0.9
Inertia Constant	H_1=5	H_2=4
Base Power	1000MVA	1000MVA
Governor Time Constant	τ_{g1} = 0.2sec	τ_{g1} = 0.3sec
Turbine Time Constant	τ_{T1} =0.5sec	τ_{T1} =0.6sec

The units are operating in parallel at the nominal frequency of 60Hz. The synchronizing power coefficient is computed from the initial operating condition and is given to be P_s = 2 p.u. A load change of 187.5 MW occurs in area1.

(a) Dertermine the new steady state frequency and the change in the tie-line flow.

(b) Construct the SIMULINK block diagram and obtain the frequency deviation response for the condition in part(a).

SIMULINK BLOCK DIAGRAM :



MANUAL CALCULATION:

RESULT:

TRANSIENT AND SMALL SIGNAL STABILITY ANALYSIS – SINGLE MACHINE INFINITE BUS SYSTEM

Expt.No :
Date :

AIM :

To become familiar with various aspects of the transient and small signal stability analysis of Single-Machine-Infinite Bus (SMIB) system

PROGRAM REQUIRED : MATLAB 5.3

THEORY :

Stability : Stability problem is concerned with the behaviour of power system when it is subjected to disturbance and is classified into small signal stability problem if the disturbances are small and transient stability problem when the disturbances are large.

Transient stability: When a power system is under steady state, the load plus transmission loss equals to the generation in the system. The generating units run a synchronous speed and system frequency, voltage, current and power flows are steady. When a large disturbance such as three phase fault, loss of load, loss of generation etc., occurs the power balance is upset and the generating units rotors experience either acceleration or deceleration. The system may come back to a steady state condition maintaining synchronism or it may break into subsystems or one or more machines may pull out of synchronism. In the former case the system is said to be stable and in the later case it is said to be unstable.

Small signal stability: When a power system is under steady state, normal operating condition, the system may be subjected to small disturbances such as variation in load and generation, change in field voltage, change in mechanical toque etc., The nature of system response to small disturbance depends on the operating conditions, the transmission system strength, types of controllers etc. Instability that may result from small disturbance may be of two forms,

(i) Steady increase in rotor angle due to lack of synchronising torque.
(ii) Rotor oscillations of increasing magnitude due to lack of sufficient damping torque.

FORMULA :

Reactive power $Q_e = \sin(\cos^{-1}(p.f))$

$$\text{Stator Current } I_t = \frac{S^*}{E_t^*}$$

$$= \frac{P_e - jQ_e}{E_t^*}$$

Voltage behind transient condition

$$E^1 = E_t + j X_d^1 I_t$$

Voltage of infinite bus

$$E_B = E_t - j(X_3 + X_{tr})I_t$$

where, $$X_3 = \frac{X_1 X_2}{X_1 + X_2}$$

Angular separation between E^1 and E_B

$$\delta o = \angle E^1 - \angle E_B$$

Prefault Operation:

$$X = j X_d^1 + jX_{tr} + \frac{X_1 X_2}{X_1 + X_2}$$

$$\text{Power } P_e = \frac{E^1 \text{ x } E_B}{X} \sin\delta_o$$

$$\delta_o = \sin^{-1}\left(\frac{P_e * X}{E^1 * E_B}\right)$$

During Fault Condition:

$$P_e = P_{Eii} = 0$$

Find out X from the equivalent circuit during fault condition

Post fault Condition:

Find out X from the equivalent circuit during post fault condition

$$\text{Power } P_e = \left\{\frac{E^1 \text{ x } E_B}{X}\right\} \sin\delta_o$$

$$\delta_{max} = \pi - \delta_o$$

$$P_e = \frac{P_m}{\sin\delta_{max}}$$

Critical Clearing Angle:

$$\text{Cos}\delta_{cr} = \frac{P_m(\boldsymbol{\delta_{max}} - \delta_o) + P_{3max}\cos\boldsymbol{\delta_{max}} - P_{2max}\cos\boldsymbol{\delta_o}}{\mathbf{P_{3max} - P_{2max}}}$$

Critical Clearing Time:

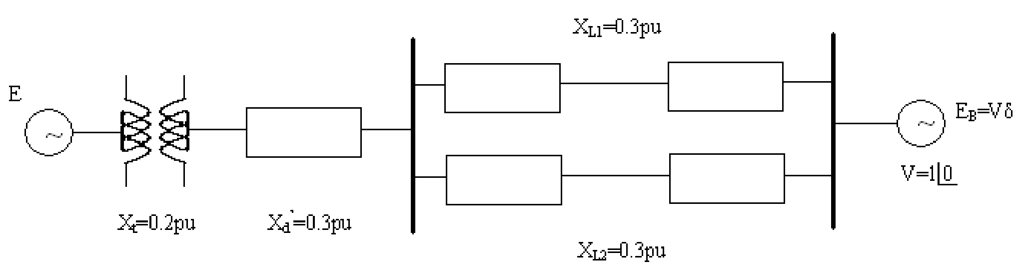
$$t_{cr} = \sqrt{\frac{2H(\delta_{cr} - \delta_o)}{\pi f_o P_m}} \quad \text{Sec}$$

PROCEDURE :

1. Enter the command window of the MATLAB.
2. Create a new M – file by selecting File - New – M – File
3. Type and save the program.
4. Execute the program by either pressing Tools – Run
5. View the results.

EXERCISE :

1. A 60Hz synchronous generator having inertia constant H = 5 MJ/MVA and a direct axis transient reactance X_d^1 = 0.3 per unit is connected to an infinite bus through a purely reactive circuit as shown in figure. Reactances are marked on the diagram on a common system base. The generator is delivering real power P_e = 0.8 per unit and Q = 0.074 per unit to the infinite bus at a voltage of V = 1 per unit.



a) A temporary three-phase fault occurs at the sending end of the line at point F.When the fault is cleared, both lines are intact. Determine the critical clearing angle and the critical fault clearing time.

.

b) Verify the result using MATLAB program.

PROGRAM :

```
Pm = 0.8;  E = 1.17;  V = 1.0;
X1 = 0.65;  X2 = inf;  X3 = 0.65;
eacfault(Pm, E, V, X1, X2, X3)
```

For b)

```
Pm = 0.8;  E = 1.17;  V = 1.0;
X1 = 0.65;  X2 = 1.8;  X3 = 0.8;
eacfault(Pm, E, V, X1, X2, X3)
```

MANUAL CALCULATION:

RESULT:

ECONOMIC DISPATCH IN POWER SYSTEMS

Expt.No :

Date :

AIM :

To understand the fundamentals of economic dispatch and solve the problem using classical method with and without line losses.

PROGRAM REQUIRED : MATLAB 5.3

THEORY :

Mathematical Model for Economic Dispatch of Thermal Units Without Transmission Loss:

Statement of Economic Dispatch Problem

In a power system, with negligible transmission loss and with N number of spinning thermal generating units the total system load PD at a particular interval can be met by different sets of generation schedules

$\{PG_1^{(k)}, PG_2^{(k)}, \ldots\ldots PG_N^{(K)}\}$; $k = 1,2,\ldots\ldots NS$

Out of these NS set of generation schedules, the system operator has to choose the set of schedules, which minimize the system operating cost, which is essentially the sum of the production cost of all the generating units. This economic dispatch problem is mathematically stated as an optimization problem.

Given : The number of available generating units N, their production cost functions, their operating limits and the system load PD,

To determine : The set of generation schedules,

$$PG_i; \quad i = 1,2\ldots\ldots N \qquad \text{——(1)}$$

Which minimize the total production cost,

$$\text{Min}; F_T = \sum_{i=1}^{N} F_i(PG_i) \qquad \text{——(2)}$$

and satisfies the power balance constraint

$$\phi = \sum_{i=1}^{N} PG_i - PD = 0 \qquad \text{——(3)}$$

and the operating limits

$PG_{i,min} \leq PG_i \leq PG_{i,max}$ ——— **(4)**

The units production cost function is usually approximated by quadratic function

$F_i(PG_i) = a_i PG^2_i + b_i PG_i + c_i$; $i = 1,2,\ldots\ldots.N$ ———**(5)**

where a_i, b_i and c_i are constants

Necessary conditions for the existence of solution to ED problem

The ED problem given by the equations (1) to (4). By omitting the inequality constraints (4) tentatively, the reduce ED problem (1),(2) and (3) may be restated as an unconstrained optimization problem by augmenting the objective function (1) with the constraint ϕ multiplied by LaGrange multiplier, λ to obtained the LaGrange function, L as

$$\text{Min : } L(PG_1 \ldots\ldots..PG_N, \lambda) = \sum_{i=1}^{N} F_i(PG_i) - \lambda \left[\sum_{i=1}^{N} PG_i - PD\right] \qquad \text{———}\mathbf{(6)}$$

The necessary conditions for the existence of solution to (6) are given by

$$\partial L / \partial PG_i = 0 = dF_i(PG_i) / dPG_i - \lambda \; ; \quad i = 1, 2, \ldots\ldots..N \qquad \text{———}\mathbf{(7)}$$

$$\partial L / \partial \lambda = 0 = \sum_{i=1}^{N} PG_i - PD \qquad \text{———}\mathbf{(8)}$$

The solution to ED problem can be obtained by solving simultaneously the necessary conditions (7) and (8) which state that the economic generation schedules not only satisfy the system power balance equation (8) but also demand that the incremental cost rates of all the units be equal be equal to λ which can be interpreted as "incremental cost of received power".

When the inequality constraints(4) are included in the ED problem the necessary condition (7) gets modified as

$$dF_i(PG_i) / dPG_i = \lambda \quad \text{for} \quad PG_{i,min} \leq PG_i \leq PG_{i,max}$$

$$\leq \lambda \quad \text{for} \quad PG_i = PG_{i,max}$$

` $$\geq \lambda \quad \text{for} \quad PG_i = PG_{i,mi} \qquad \text{\_\_\_\_}(9)$$

Economic Schedule

$$PG_i = (\lambda - b_i) / 2a_i \; ; \quad i=1,2\ldots\ldots\ldots\ldots\ldots.N \qquad \text{———}\mathbf{(10)}$$

Incremental fuel cost

$$\lambda = \left[PD + \sum_{i=1}^{N} (b_i/2a_i) \right] / \sum_{i=1}^{N} (1/2a_i) \qquad \text{——} \quad \textbf{(11)}$$

PROCEDURE :

1. Enter the command window of the MATLAB.
2. Create a new M – file by selecting File - New – M – File
3. Type and save the program.
4. Execute the program by either pressing Tools – Run.
5. View the results.

EXERCISE :

1.The fuel cost functions for three thermal plants in $/h are given by

$C_1 = 500 + 5.3\ P_1 + 0.004\ P_1^2$; P_1 in MW

$C_2 = 400 + 5.5\ P_2 + 0.006\ P_2^2$; P_2 in MW

$C_3 = 200 + 5.8\ P_3 + 0.009\ P_3^2$; P_3 in MW

The total load , P_D is 800MW.Neglecting line losses and generator limits, find the optimal dispatch and the total cost in $/h by analytical method. Verify the result using MATLAB program.

PROGRAM :

```
alpha = [500; 400; 200];
beta = [5.3; 5.5; 5.8]; gamma = [0.004; 0.006; 0.009];
PD = 800;
DelP = 10;
lamda = input('Enter estimated value of Lamda = ');
fprintf(' ')
disp(['Lamda P1 P2 P3 DP'...
      ' grad Delamda'])
      iter = 0;
   while abs(DelP) >= 0.001
```

```
    iter = iter + 1;
    P = (lamda - beta)./(2*gamma);
    DelP = PD - sum(P);
    J = sum(ones(length(gamma),1)./(2*gamma));
    Delamda = DelP/J;
    disp([lamda,P(1),P(2),P(3),DelP,J,Delamda])
    lamda = lamda + Delamda;
end
totalcost = sum(alpha + beta.*P + gamma.*P.^2)
```

MANUAL CALCULATION:

2. The fuel cost functions for three thermal plants in \$/h are given by

$C_1 = 500 + 5.3\, P_1 + 0.004\, P_1^2$; P_1 in MW

$C_2 = 400 + 5.5\, P_2 + 0.006\, P_2^2$; P_2 in MW

$C_3 = 200 + 5.8\, P_3 + 0.009\, P_3^2$; P_3 in MW

The total load , P_D is 975MW.

Generation limits:

$200 \le P_1 \le 450$ MW
$150 \le P_2 \le 350$ MW
$100 \le P_3 \le 225$ MW

Find the optimal dispatch and the total cost in \$/h by analytical method. Verify the result using MATLAB program.

PROGRAM :

```
cost = [500 5.3 0.004
   400 5.5 0.006
   200 5.8 0.009];
mwlimits = [200 450
          150 350
            100 225];
Pdt = 975;
dispatch
gencost
```

MANUAL CALCULATION:

RESULT :