Power Flow Analysis using MATLAB®

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بسم الله الرحمن الرحيم

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Power Flow Analysis using Matlab@

A Thesis presented to

The Academic Faculty

By

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In partial fulfillment of requirement for the Degree of Higher Diploma in Electrical and Electronic Engineering (EEE)

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Declaration

This is to certify that the project entitled ”Power Flow Analysis Using Matlab@ “is

supervised by

Rakibul Hasan Sagor . This Project Work has been submitted anywhere for a degree or diploma.

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To our parents &uncle

You are the light of our life.

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CHAPTER 1

1.1 INTRODUCTION:

The system is assumed 3-phase balanced operating in a steady state and stable condition. It is represented by a single phase diagram on a per-unit basis, with a system wide MVA base, and a voltage base properly chosen on each side of every transformer. The base MVA and base V are specified/ known everywhere in the system. The most common way to represent such a system is to use the node-voltage method. Given the voltages of generators at all generator nodes, and knowing all impedances of machines and loads, one can solve for all the currents in the typical node voltage analysis first the generators are replaced by methods using Kirchhoff's current law first the generators are replaced by equivalent current sources and the node equations are written in the form:

$$\boldsymbol{I} = \boldsymbol{YV} \qquad (1.1)$$

Where I is the injected current vector, Y is the admittance matrix and V is the node voltage vector. These equations are easy to write by inspection of the circuit. The problem is not so simple in real power circuits and systems. Usually in generator nodes only the real power and voltage are known .thus not enough variable are known to solve an equation of the form I = YV.in fact the power is a nonlinear function of the current and voltage, the solution of the resulting equations (while it may exist)is not easy! In fact there is no known analytical method to find the solution. As a result iterative techniques are used to find the solution (voltage, current, etc.), the nonlinear set of equations which are generated are called power flow equations. The solution of such equations results in a power flow study or load flow analysis. Such studies are the backbone of power system studies, for analysis, design, control, and economic operation of the power system. they are also essential for transient analysis of the system.

1.2 Bus Admittance Matrix

In order to obtained the node voltage equations consider the simple power system in figure (1.1), where impedances is express in per unit and for simplicity the resistances is neglected, to find the node current by KCL the impedance must be converted to admittance shows in equation (1.2)

$$\mathbf{y_{ij}} = \frac{\mathbf{1}}{\mathbf{z_{ij}}} = \frac{\mathbf{1}}{\mathbf{r_{ij}+x_{ij}}} \qquad (1.2)$$

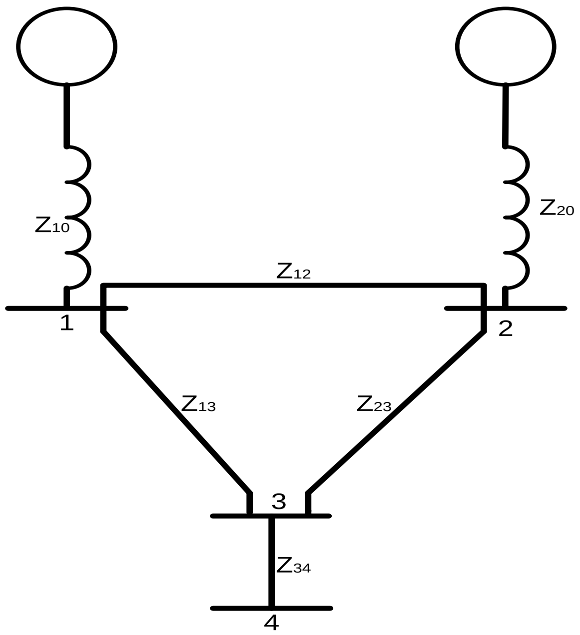
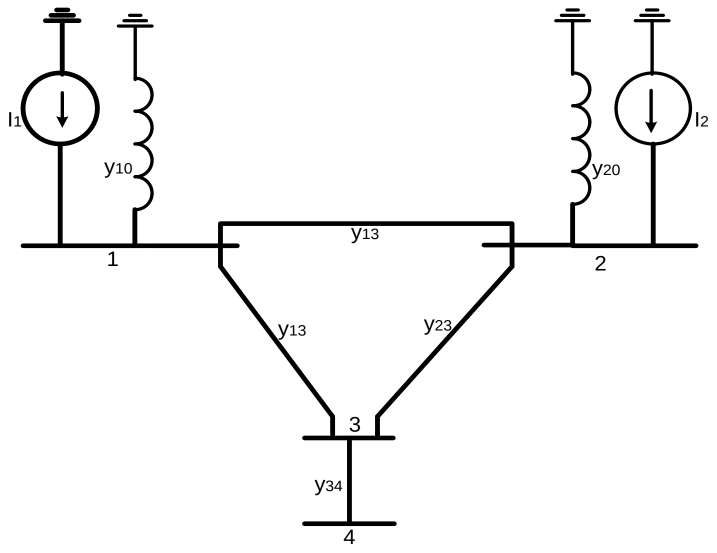


Figure (1.1)



Figure(1.2)

The circuit has been redrawn in figure (1.2) in terms of admittances and transformation to current sources. Node 0 (which is normally ground) is taken as reference. Applying KCL to the independent nodes 1 through 4 result in

$$\boldsymbol{I_1 = y_{10}V_1 + y_{12}(V_1 - V_2) + y_{13}(V_1 - V_3)} \quad (1.3)$$

$$\boldsymbol{I_2 = y_{20}V_2 + y_{12}(V_2 - V_1) + y_{23}(V_2 - V_3)} \quad (1.4)$$

$$\boldsymbol{0 = y_{23}(V_3 - V_2) + y_{13}(V_3 - V_1) + y_{34}(V_3 - V_4)} \quad (1.5)$$

$$\boldsymbol{0 = y_{34}(V_3 - V_4)} \quad (1.6)$$

Rearranging these equations

$$I_1 = (y_{10} + y_{12} + y_{13})V_1 - y_{12}V_2 - y_{13}V_3$$

$$I_2 = -y_{12}V_1 + (y_{20} + y_{12} + y_{23})V_2 - y_{23}V_3$$

$$0 = -y_{13}V_1 - y_{23}V_2 + (y_{13} + y_{23} + y_{34})V_3 - y_{34}V_4$$

$$0 = -y_{34}V_3 + y_{34}V_4$$

So the result is the following admittances

$$Y_{11} = y_{10} + y_{12} + y_{13}$$

$$Y_{22} = y_{20} + y_{12} + y_{23}$$

$$Y_{33} = y_{13} + y_{23} + y_{34}$$

$$Y_{44} = y_{34}$$

$$Y_{12} = y_{21} = -y_{12}$$

$$Y_{13} = y_{31} = -y_{13}$$

$$Y_{23} = y_{32} = -y_{23}$$

$$Y_{23} = y_{32} = -y_{23}$$

$$Y_{34} = y_{34} = -y_{34}$$

The node equation can be reduced to

$$I_1 = Y_{11}V_1 + Y_{12}V_2 + Y_{13}V_3 + Y_{14}V_4$$

$$I_2 = Y_{12}V_1 + Y_{22}V_2 + Y_{32}V_3 + Y_{24}V_4$$

$$I_3 = Y_{13}V_1 + Y_{23}V_2 + Y_{33}V_3 + Y_{34}V_4$$

$$I_4 = Y_{41}V_1 + Y_{42}V_2 + Y_{43}V_3 + Y_{44}V_4$$

But in the network shown in figure (1.1), There is no connection between bus 1 and bus 4, So $\boldsymbol{Y_{14} = 0}$. Similarly,

$$\boldsymbol{Y_{24} = Y_{42} = 0}.$$

$$\begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_i \\ \vdots \\ I_n \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & \cdots & Y_{1i} & \cdots & Y_{1n} \\ Y_{21} & Y_{22} & \cdots & Y_{2i} & \cdots & Y_{2n} \\ \vdots & \vdots & & \vdots & & \vdots \\ Y_{i1} & Y_{i2} & \cdots & Y_{ii} & \cdots & Y_{in} \\ \vdots & \vdots & & \vdots & & \vdots \\ Y_{n1} & Y_{n2} & \cdots & Y_{ni} & \cdots & Y_{nn} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ \vdots \\ V_i \\ \vdots \\ V_n \end{bmatrix} \qquad (1.7)$$

Diagonal element ($\boldsymbol{Y_{11}}$) is called mutual admittance and off diagonal element ($\boldsymbol{Y_{12}}$) is called self-admittance.

So we can write the expression for $\boldsymbol{I_{bus}}$ which is

$$\boldsymbol{I_{bus} = Y_{bus}V_{bus}} \qquad (1.8)$$

$\boldsymbol{I_{bus}}$ is the vector injected bus current which is positive when it is flows towards the bus and it is negative when it is away from the bus $\boldsymbol{V_{bus}}$ the vector of bus magnitude measured from the reference node , $\boldsymbol{Y_{bus}}$ is known as the bus admittance matrix.

$$\boldsymbol{Y_{ii} = \sum_{j=0}^{n} y_{ij}}$$

The off-diagonal element is equal to the negative of the admittance between the nodes. It is known as the mutual admittance or transfer admittance,

$$\boldsymbol{Y_{ii} = Y_{ji} = -y_{ij}}$$

$$\boldsymbol{V_{bus} = Y_{bus}^{-1} I_{bus}}$$

The inverse of admittance matrix is called bus impedance matrix $\boldsymbol{Z_{bus}}$.

CHAPTER 2

2.1 Solution of Nonlinear Algebraic Equations

Large numbers of iterations are require to solve load flow equation using both $\boldsymbol{Y_{bus}}$ and $\boldsymbol{Z_{bus}}$. For efficient calculation, the program should have following features: High speed, fast convergent, Minimal storage, Simplicity and ease of programming, reliability for all condition of the system.

The factors of convergence is very high and low series impedances ,long EHV lines ,large series capacitances, series and shunt compensation, The most method of solving nonlinear equations are Gauss-Seidel , Newton-Raphson methods which are discuss as follow:

2.2 Gauss –Seidel Method:

The method of Gauss-Seidel is known as the method of successive displacements ,To illustrate the technique, Consider the solution of the nonlinear equation given by

$$\boldsymbol{f(x) = 0} \qquad (\mathbf{2.1})$$

Rearranging the above equation we can write

$$\boldsymbol{x = g(x)} \qquad (\mathbf{2.2})$$

If $\boldsymbol{x^{(k)}}$ is an initial estimate of the variable x , the follow iterative sequence is formed.

$$\boldsymbol{x^{(k+1)} = g\left(x^{(k)}\right)} \qquad \boldsymbol{k = 0, 1, 2, 3, \ldots.} \qquad (\mathbf{2.3})$$

The solution is obtained when the difference between the absolute value of the successive iteration is less than a specified accuracy.

$$|x^{(k+1)} - x^{(k)}| \leq \in \qquad (2.4)$$

Where ∈ is the desired accuracy.

Example 2.1:

Using the Gauss –Seidel method to find a root of the following equation.

$$f(x) = x^3 - 6x^2 + 9x - 4 = 0$$

Solving for x , the above expiration is

$$x = -\frac{1}{9}x^3 + \frac{6}{9}x^2 + \frac{4}{9} = g(x)$$

Considering the acceleration factor of α =1.25, where the starting initial estimation of $x^{(0)} = 2$

$$g(2) = -\frac{1}{9}(2)^3 + \frac{6}{9}(2)^2 + \frac{4}{9} = 2.2222$$

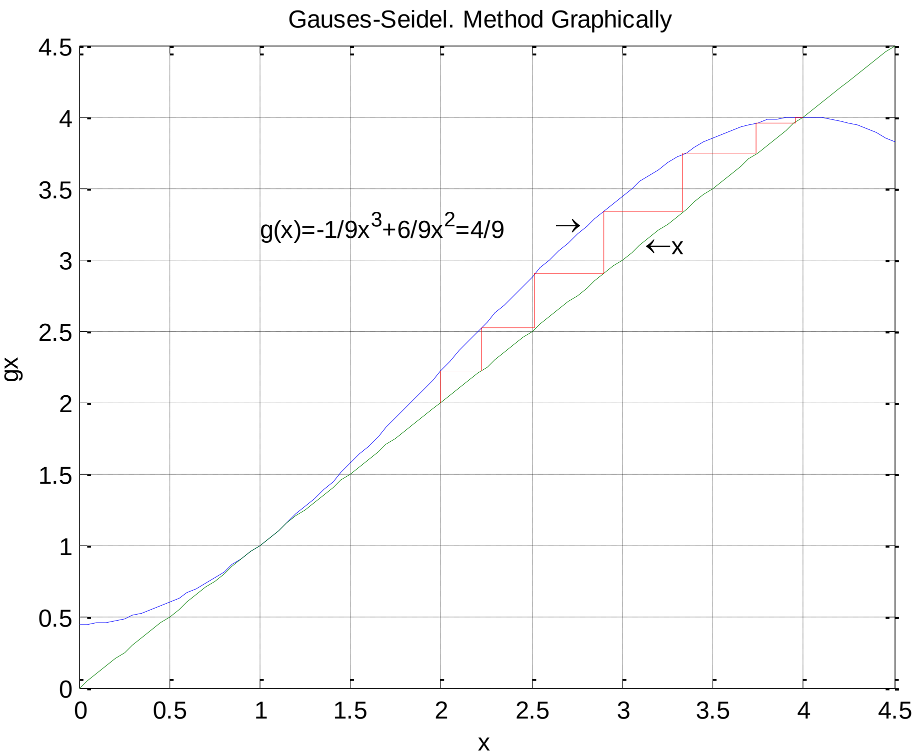
$$x^{(1)} = 2 + 1.25[2.2222 - 2] = 2.2778$$

The second iteration is

$$g(2.2778) = -\frac{1}{9}(2.2778)^3 + \frac{6}{9}(2.2778)^2 + \frac{4}{9} = 2.5902$$

$$x^{(2)} = 2.2778 + 1.25[2.5902 - 2.2778] = 2.6683$$

The subsequent iteration result in 3.0801, 3.1831, 3.7238, 4.0084, 3.9978 and 4.0005, Where the effect of iteration is graphically shown in matlab.



Figure(2.1)

Where now consider the n equations in n variables

$$f_1 = (x_{1,}x_2, \ldots\ldots, x_n) = c_1$$

$$f_2 = (x_{1,}x_2, \ldots\ldots, x_n) = c_2 \qquad (2.5)$$

……………………………….

$$f_1 = (x_{1,} x_2, \ldots\ldots, x_n) = c_n$$

Solving of one variable from each equation, the above functions are rearranged and written as

$$x_1 = c_1 + g_1(x_{1,} x_2, \ldots\ldots, x_n)$$

$$x_2 = c_2 + g_2(x_{1,} x_2, \ldots\ldots, x_n) \qquad (2.6)$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$x_n = c_n + g_n(x_{1,} x_2, \ldots\ldots, x_n)$$

The iteration procedure is initialed by assuming an approximate solution for each of the independent variables ($x_1^{(0)}$, $x_2^{(0)}$,…,$x_n^{(0)}$) which the result of this equation is new equation which is ($x_1^{(1)}$, $x_2^{(1)}$,…,$x_n^{(1)}$) ,calculated by Gauss-Seidel method, at the end of each iteration the calculated values of all variables are tested against the previous values. If the variables are with the specific accuracy a solution has converged, otherwise iteration must be performed. The rate of convergence can often be increased by using a suitable acceleration factor α, and the iterative sequence becomes

$$x_i^{(k+1)} = x_i^{(k)} + \alpha\left(x_{i\,cal}^{(k+1)} + x_i^{(k)}\right) \qquad (2.7)$$

The output is

Iter	g	dx	x
1	2.2222	0.2222	2.2778
2	2.5902	0.3124	2.6683
3	3.0801	0.4118	3.1831
4	3.6157	0.4326	3.7238
5	3.9515	0.2277	4.0084
6	4.0000	-0.0085	3.9978
7	4.0000	0.0022	4.0005
8	4.0000	-0.0005	3.9999

2.3 Newton-Raphson Method

The most widely used method for solving simultaneous nonlinear algebraic equations is the Newton –Raphson method. Newton's method is a successive approximation procedure based on an initial estimate of the unknown and the use of Taylor's series expansion. Consider the solution of the one-dimensional equation given by

$$\boldsymbol{f(x) = c} \qquad (\mathbf{2.8})$$

If $\boldsymbol{x}^{(0)}$ is an initial estimate of the solution, and $\Delta\boldsymbol{x}^{(0)}$ is a small deviation formed the correct solution, ''we must have''

$$\boldsymbol{f}\left(\boldsymbol{x}^{(0)} + \Delta\boldsymbol{x}^{(0)}\right) = \boldsymbol{c}$$

Expand the left hand side of the above equation in Taylor's series about $\boldsymbol{x}^{(0)}$ yields

$\boldsymbol{f}\left(\boldsymbol{x}^{(0)}\right) + (\frac{\boldsymbol{df}}{\boldsymbol{dx}})^{(\mathbf{0})}\,\Delta\boldsymbol{x}^{(0)} + \frac{\mathbf{1}}{\mathbf{2}!}(\ \Delta\boldsymbol{x}^{(0)})^{\mathbf{2}}+\ldots=C$

Assuming the error $\Delta\boldsymbol{x}^{(0)}$ is very small, the higher order terms can be neglected which results in

$\Delta\boldsymbol{c}^{(\mathbf{0})} \cong (\frac{\boldsymbol{df}}{\boldsymbol{dx}})^{(\mathbf{0})}\quad \Delta\boldsymbol{x}^{(0)}$

Where

$$\Delta\boldsymbol{c}^{(\mathbf{0})} = \boldsymbol{c} - \boldsymbol{f}\left(\boldsymbol{x}^{(0)}\right)$$

Adding $\Delta\boldsymbol{x}^{(0)}$ to the initial estimate will result in the second approximation

$$\boldsymbol{x}^{(\mathbf{1})} = \boldsymbol{x}^{(\mathbf{0})} + \frac{\Delta\boldsymbol{c}^{(\mathbf{0})}}{(\frac{\boldsymbol{df}}{\boldsymbol{dx}})^{(\mathbf{0})}}$$

Successive use of this procedure yields the Newton-Raphson algorithm

$$\Delta\boldsymbol{c}^{(\boldsymbol{k})} = \boldsymbol{c} - \boldsymbol{f}\left(\boldsymbol{x}^{(\boldsymbol{k})}\right) \qquad (\mathbf{2.9})$$

$$\Delta\boldsymbol{x}^{(\boldsymbol{k})} = \frac{\Delta\boldsymbol{c}^{(\boldsymbol{k})}}{(\frac{\boldsymbol{df}}{\boldsymbol{dx}})^{(\boldsymbol{k})}} \qquad (\mathbf{2.10})$$

$$\boldsymbol{x}^{(\boldsymbol{k}+\mathbf{1})} = \boldsymbol{x}^{(\boldsymbol{k})} + \Delta\boldsymbol{x}^{(\boldsymbol{k})} \qquad (\mathbf{2.11})$$

The equation (2.8) can be rearranged as

$$\Delta \boldsymbol{c}^{(\boldsymbol{k})} = \boldsymbol{j}^{\boldsymbol{k}} \Delta \boldsymbol{x}^{(\boldsymbol{k})} \qquad (\mathbf{2.12})$$

Where

$$\boldsymbol{j}^{(\boldsymbol{k})} = (\frac{\boldsymbol{df}}{\boldsymbol{dx}})^{(\boldsymbol{k})}$$

The relation in (2.10) demonstrates that the nonlinear equation $\boldsymbol{f}(\boldsymbol{x}) - \boldsymbol{c} = \mathbf{0}$ is approximated by the tangent line on the curve at $\boldsymbol{x}^{(\boldsymbol{k})}$. Therefore, a linear equation is obtained in terms of the small changes in the variable. The intersection of the tangent line with the x-axis results in $\boldsymbol{x}^{(\boldsymbol{k+1})}$ .this idea is demonstrated graphically in the following example

Example 2.2:

Use the Newton–Raphson method find a root of the equation

$$\boldsymbol{f}(\boldsymbol{x}) = \boldsymbol{x}^{\mathbf{3}} - \mathbf{6}\boldsymbol{x}^{\mathbf{2}} + \mathbf{9} - \mathbf{4} = \mathbf{0}$$

Assume the initial estimate of $\boldsymbol{x}^{(\mathbf{0})} = \mathbf{6}$

The matlab program is given in the last of this chapter, where the graph is follow

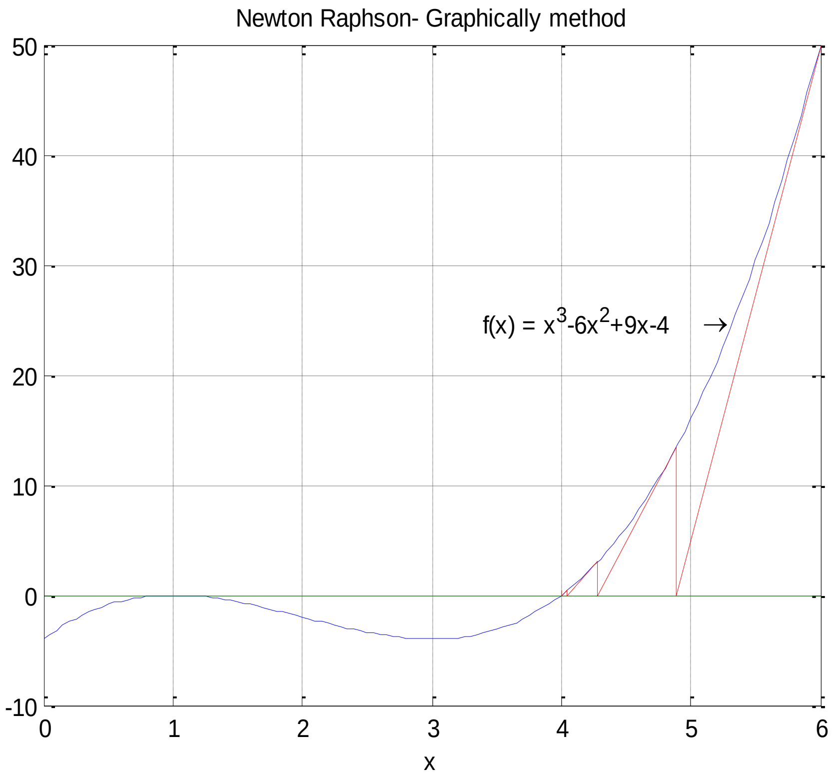


Figure (2.1)

The graphically description of the Newton-Raphson method. Starting with the initial estimate of $\boldsymbol{x^{(0)}=6}$, We extrapolate along the tangent to its intersection with the x-axis and take that as the next approximation. This is continued until successive x-values are sufficiently close. The analytical solution is given by the Newton-Raphson algorithm is

$$\frac{df(x)}{dx} = 3x^2 - 12x + 9$$

$$\Delta c^{(0)} = c - f\left(x^{(0)}\right) = 0 - [(6)^3 - 6(6)^2 + 9(6) - 4] = -50$$

$$\left(\frac{df}{dx}\right)^{(0)} = 3(6)^2 - 12(6) + 9 = 45$$

Therefore, The result at the end of the first iteration is

$$x^{(1)} = x^{(0)} + \Delta c^{(0)} = 6 - 1.1111 = 4.8889$$

The subsequent iterations result in

$$x^{(2)} = x^{(1)} + \Delta c^{(1)} = 4.8889 - \frac{13.4431}{22.037} = 4.2789$$

$$x^{(3)} = x^{(2)} + \Delta c^{(2)} = 4.2789 - \frac{2.9981}{12.5797} = 4.0011$$

$$x^{(4)} = x^{(3)} + \Delta c^{(3)} = 4.0405 - \frac{0.3748}{9.4914} = 4.0011$$

$$x^{(5)} = x^{(4)} + \Delta c^{(4)} = 4.0011 - \frac{0.0095}{9.0126} = 4.0000$$

The method may converge to a root different from the expected one or diverge if the starting value is not close enough to the root. The result of the iteration by newton method is

Enter the initial estimate -> 6

iter	Dc	J	dx	X
1	-50.0000	45.0000	-1.1111	4.8889
2	-13.4431	22.0370	-0.6100	4.2789
3	-2.9981	12.5797	-0.2383	4.0405
4	-0.3748	9.4914	-0.0395	4.0011
5	-0.0095	9.0126	-0.0011	4.0000
6	0.0000	9.0000	-0.0000	4.000

Consider the n-dimensional equations given by (2.6). Expanding left hand side of the equations (2.6) in the Taylor's series about the initial estimates and neglecting all higher order terms leads to the expression.

$$(f_1)^{(0)} + (\frac{\partial f_1}{\partial x_1})^{(0)}\ \Delta x_1^{(0)} + (\frac{\partial f_1}{\partial x_2})^{(0)}\ \Delta x_2^{(0)} + \cdots + (\frac{\partial f_1}{\partial x_n})^{(0)}\ \Delta x_n^{(0)} = c_1$$

$$(f_2)^{(0)} + (\frac{\partial f_2}{\partial x_1})^{(0)}\ \Delta x_1^{(0)} + (\frac{\partial f_2}{\partial x_2})^{(0)}\ \Delta x_2^{(0)} + \cdots + (\frac{\partial f_2}{\partial x_n})^{(0)}\ \Delta x_n^{(0)} = c_2$$

$$(f_n)^{(0)} + (\frac{\partial f_n}{\partial x_1})^{(0)}\ \Delta x_1^{(0)} + (\frac{\partial f_n}{\partial x_2})^{(0)}\ \Delta x_2^{(0)} + \cdots + (\frac{\partial f_n}{\partial x_n})^{(0)}\ \Delta x_n^{(0)} = c_n$$

We can be written as

$$\Delta C^{(k)} = J^{(k)}\Delta X^{(k)}$$

Or

$$\Delta \boldsymbol{X}^{(k)} = [\boldsymbol{J}^{(k)}]^{-1} \Delta \boldsymbol{C}^{(k)} \qquad (\mathbf{2.13})$$

And the Newton-Raphson algorithm for the n-dimensional case becomes

$$\boldsymbol{X}^{(k+1)} = \boldsymbol{X}^{(k)} + \Delta \boldsymbol{X}^{(k)} \qquad (\mathbf{2.13})$$

Where

$$\Delta \boldsymbol{X}^{(k)} = \begin{bmatrix} \Delta x_1^{(k)} \\ \Delta x_2^{(k)} \\ \vdots \\ \Delta x_n^{(k)} \end{bmatrix} \quad \text{and} \quad \Delta \boldsymbol{C}^{(k)} = \begin{bmatrix} c_1 - (f_1)^{(k)} \\ c_2 - (f_2)^{(k)} \\ \vdots \\ c_n - (f_n)^{(k)} \end{bmatrix}$$

$$\boldsymbol{J}^{(k)} = \begin{bmatrix} (\frac{\partial f_1}{\partial x_1})^{(k)} & (\frac{\partial f_2}{\partial x_2})^{(k)} & \cdots & (\frac{\partial f_1}{\partial x_n})^{(k)} \\ (\frac{\partial f_2}{\partial x_1})^{(k)} & (\frac{\partial f_2}{\partial x_2})^{(k)} & \cdots & (\frac{\partial f_2}{\partial x_n})^{(k)} \\ \vdots & \vdots & \ddots & \cdots \\ (\frac{\partial f_n}{\partial x_1})^{(k)} & (\frac{\partial f_n}{\partial x_2})^{(k)} & \cdots & (\frac{\partial f_n}{\partial x_n})^{(k)} \end{bmatrix}$$

$\boldsymbol{J}^{(k)}$ is called the Jacobian matrix. Elements of this matrix are the partial derivatives evaluated at $\boldsymbol{X}^{(k)}$. It is assumed that $\boldsymbol{J}^{(k)}$ has an inverse during each iteration. Newton's method is applied to set of nonlinear equations, to reduce the problem of solving linear equations in order to determine the values that improve the accuracy of the estimates.

Matlab program for the chapter 2 examples

Example (2.1), Figure (2.1)

```
% figure 2.
%plot the following eqution
% x=-x^3/9+6/9*x^2+4/9=gx
s1=[]; s2=[];
x=0:0.05:4.5;
g=-1/9*x.^3+6/9*x.^2+4/9;
k=1;
dz=10; z=2;
s1(k)=z;
s2(k)=z;
while dz>0.01
k=k+2;
s1(k-1)=z;
p=-1/9*z^3+6/9*z^2+4/9;
s2(k-1)=p;
dz=abs(z-p);
z=z+1.25*(p-z);
s1(k)=z;
s2(k)=p; end
plot(x,g,'-',x,x,'-',s1,s2,'-'),grid
xlabel('x')
text(1,3.25,'g(x)=-1/9x^3+6/9x^2=4/9')
text(3.425,3.25 , 'x')
text(2.625,3.275,'\rightarrow')
text(3.3,3.27,'\leftarrow')
clear x g r
```

The program for getting output is

Example (2.2), Figure (2.2)

```
figure2.1
dx=1;
x=2;
iter = 0;           % Iteration counter
disp('Iter    g          dx          x') % Heading
for results
while abs(dx) >= 0.001 & iter < 100 % Test for
convergence
iter = iter +     % No. of iterations
g = -1/9*x^3+6/9*x^2+4/9;
dx = g-x;                                 % Change in
variable
x = x + 1.25*dx; % Successive approximation with
1.25 accel. factor
fprintf('%g', iter), disp([g, dx, x])
end
grid on
```

```
z=6;
s1(k)=z;
while abs(dz) >.1
Df= z^3-6*z^2+9*z -4;
s2(k)=Df;
s1(k)=z;
J = 3*z^2-12*z+9;
dz=-Df/J;
z=z+dz;
k=k+2;
s1(k-1)=z;
s2(k-1)=0;
s1(k)=z;
s2(k)=Df;
end
h=zeros(1,length(x));
plot(x,f,'-', x,h,'-', s1,s2,'-'),grid
xlabel('x')
text(3.4, 25,'f(x) = x^3-6x^2+9x-4')
text(5.1, 25, '\rightarrow')
```

The matlab program for getting output is :

```
%Newton2.2
dx=1;     % Change in variable is set to a high
value
x=input('Enter the initial estimate -> '); %
Initial     %estimate
iter = 0;                        %Iteration counter
disp('iter   Dc   J     dx           x')% Heading
for result
while abs(dx) >= 0.001 & iter < 100             %
Test for %convergence
iter = iter + 1;                         % No. of
iterations
Dc=4 - (x^3-6*x^2+9*x);                         %
Residual
J = 3*x^2-12*x+9;                    % Derivative
dx= Dc/J;                              %Change in
variable
x=x+dx;                              % Successive
solution
fprintf('%g', iter), disp([Dc, J, dx, x])
end
```

CHAPTER 3

3.1 Power flow solution

The power flow studies, commonly known as load flow, form an important part of power system analysis ,they are necessary for planning, economic scheduling ,and control of an existing system as well as planning its future expansion, the problem consists of determining the magnitudes and phase angle of voltages at each bus and active and reactive power flow in each line.

In solving a power flow problem, the system is assumed to be operating under balanced conditions and a single-phase model is used .four quantities are associated with each bus .these are voltage magnitude $|\boldsymbol{V}|$,phase angle $\boldsymbol{\delta}$,real power $\boldsymbol{P}$,and reactive power $\boldsymbol{Q}$,the system buses are generally classified in to three types.

3.1.1 Slack bus

One bus, known as slack or swing bus, is taken as reference where the magnitude and phase angle of the voltage are specified. The losses is remained unknown until the load flow solution is complete, this because of the additional real and reactive power is determine by this bus since the voltage magnitude is considering 1.0 per unit so the angle should be zero, generally the bus connected to the large generating station. Is considering.

3.1.2 Regulated buses

These buses are the generator buses. They are also known as voltage –controlled buses. At these buses, the real power and voltage magnitude are specified. The phase angles of the voltages and the reactive power are to be determined. The limits on the value of the reactive power are also specified. These buses are called p-v buses.

3.1.3 Load buses

At these buses the active and reactive powers are specified .the magnitude and the phase angle of the bus voltages are unknown. Buses nether generating bus of nor load bus is zero, but if buses are at the same time load and generating bus then , it treat as negative generation These buses are called $\boldsymbol{P-Q}$ buses.

3.2 Power flow equation

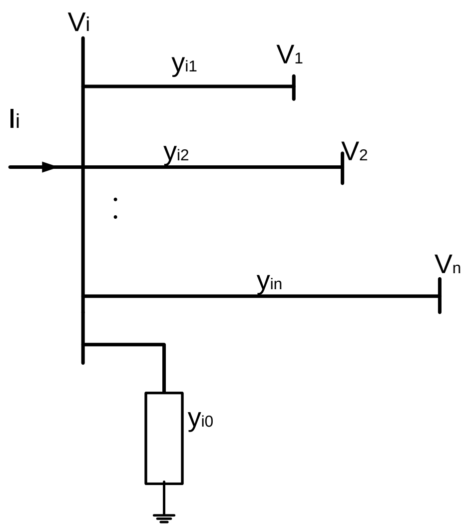
Consider a typical bus of a power system network as shown in the figure (3.1) the Transmission lines are represented by their equivalent $\boldsymbol{\pi}$ models where impedances have been converted to per unit admittances on a common MVA base.

Application of KCL to this bus results in

$$\boldsymbol{I_i = y_{i0}V_i + y_{i1}(V_i - V_1) + y_{i2}(V_i - V_2) + \cdots + y_{in}(V_i - V_n)}$$

$$= \boldsymbol{(y_{i0} + y_{i1} + y_{i2} + \cdots + y_{in})V_i - y_{i1}V_1 - y_{i2}V_2 - \cdots - y_{in}V_n)} \quad (3.1)$$

$$\boldsymbol{I_i = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j} \qquad \boldsymbol{j \neq i} \qquad (3.2)$$



Figure(3.1)

The real and reactive power at bus $\boldsymbol{i}$ is

$$\mathrm{P_i} + \mathrm{jQ_i} = \mathrm{V_i I_i^*} \qquad (3.3)$$

Or

$$\boldsymbol{I_i} = \frac{\boldsymbol{P_i - jQ_i}}{\boldsymbol{V_i^*}} \qquad (3.4)$$

$$\frac{\boldsymbol{P_i - jQ_i}}{\boldsymbol{V_i^*}} = \boldsymbol{V_i} \sum_{\boldsymbol{j=0}}^{\boldsymbol{n}} \boldsymbol{y_{ij}} - \sum_{\boldsymbol{j=1}}^{\boldsymbol{n}} \boldsymbol{y_{ij}} \boldsymbol{V_j} \qquad \boldsymbol{j \neq i} \qquad (3.5)$$

3.3 Gauss-Seidel Power Flow Solution

In the power flow study, it is necessary to solve the set of nonlinear equations represented by (3.5) for two unknown variables at each node. Using the Gauss-Seidel method (3.5) is solved for $\boldsymbol{V_i}$, and the iterative sequence becomes

$$\boldsymbol{V_i^{(k+1)}} = \frac{\frac{\boldsymbol{P_i^{sch} - jQ_i^{sch}}}{\boldsymbol{V_i^{*(k)}}} + \sum \boldsymbol{y_{ij} V_j^{(k)}}}{\sum \boldsymbol{y_{ij}}} \qquad \boldsymbol{j \neq i} \qquad (3.6)$$

Where $\boldsymbol{y_{ij}}$ shown in lowercase letter is the actual admittance in per unit. $\boldsymbol{P_i^{sch}}$ and $\boldsymbol{Q_i^{sch}}$ are the real and reactive powers expressed in per unit. Applying KCL, current entering bus $\boldsymbol{i}$ was assumed positive. Thus, for buses where real and reactive powers are injected into the bus, such as generator buses, $\boldsymbol{P_i^{sch}}$and $\boldsymbol{Q_i^{sch}}$ have positive values. For load buses where real and reactive powers are flowing away from the bus, $\boldsymbol{P_i^{sch}}$and $\boldsymbol{Q_i^{sch}}$have negative values. If (3.5) is solved for $\boldsymbol{P_i}$ and $\boldsymbol{Q_i}$, we have

$$\boldsymbol{P_i^{(k+1)}} = \Re\left\{\boldsymbol{V_i^{*(k)}}\left[\boldsymbol{V_i^{(k)}} \sum_{\boldsymbol{j=0}}^{\boldsymbol{n}} \boldsymbol{y_{ij}} - \sum_{\boldsymbol{j=1}}^{\boldsymbol{n}} \boldsymbol{y_{ij}} \boldsymbol{V_j^{(k)}}\right]\right\} \qquad \boldsymbol{j \neq i} \quad (3.7)$$

$$\boldsymbol{Q_i^{(k+1)}} = -\Im\left\{\boldsymbol{V_i^{*(k)}}\left[\boldsymbol{V_i^{(k)}} \sum_{\boldsymbol{j=0}}^{\boldsymbol{n}} \boldsymbol{y_{ij}} - \sum_{\boldsymbol{j=1}}^{\boldsymbol{n}} \boldsymbol{y_{ij}} \boldsymbol{V_j^{(k)}}\right]\right\} \quad \boldsymbol{j \neq i} \qquad (3.8)$$

The load flow equation is usually expressed in terms of the elements of the bus admittance matrix. Since the off- diagonal elements of the bus admittance matrix $\boldsymbol{y_{bus}}$, Shown the uppercase latters, are $\boldsymbol{Y_{ij} = -y_{ij}}$,and the diagonal elements are $\boldsymbol{Y_{ij} = \sum y_{ij}}$,(3.6) becomes

$$\boldsymbol{V_i^{(k+1)}} = \frac{\frac{P_i^{sch} - jQ_i^{sch}}{V_i^{*(k)}} + \sum_{j \neq i} Y_{ij} V_j^{(k)}}{Y_{ii}} \qquad (3.9)$$

$$\boldsymbol{P_i^{(k+1)}} = \Re\left\{\boldsymbol{V_i^{*(k)}}\left[\boldsymbol{V_i^{(k)} Y_{ii}} + \sum_{\substack{j=1 \\ j \neq i}}^{n} \boldsymbol{y_{ij} V_j^{(k)}}\right]\right\} \qquad \boldsymbol{j \neq i} \quad (3.10)$$

$$\boldsymbol{Q_i^{(k+1)}} = -\Im\left\{\boldsymbol{V_i^{*(k)}}\left[\boldsymbol{V_i^{(k)} Y_{ii}} + \sum_{\substack{j=1 \\ j \neq i}}^{n} \boldsymbol{y_{ij} V_j^{(k)}}\right]\right\} \qquad \boldsymbol{j \neq i} \quad (3.11)$$

$\boldsymbol{Y_{ii}}$ Include the admittance to ground of line changing susceptance and any other fixed admittance to ground. Since both component of voltage are specified for slack bus, there are 2(n-1) equations which must be solved by an iterative method, under normal operating conditions, the voltage magnitude of the buses are in neighborhood of 1.0 per unit or closed to the voltage magnitude of the slack bus.

Voltage magnitude at the load buses are somewhat lower than the slack bus value, Depending on the reactive power demand, whereas the scheduled voltage at the generator buses are somewhat higher also, the phase angle of the load buses are below the reference angle in accordance to the real power demand, whereas the phase angle of the generator buses may be above the reference value depending on the amount of real power flowing in to the bus. Thus, for the Gauss-Seidel method, an initial voltage estimate of 1.0+j0.0 for unknown voltages is satisfactory, and the converged solution correlates with the actual operating states.

For P-Q buses, the real and reactive powers $\boldsymbol{P_i^{sch}}$ and $\boldsymbol{Q_i^{sch}}$ are known. Starting with an initial estimate, (3.9) is solved for the real and imaginary components of voltage. For the voltage controlled buses (P-V buses).

Where $\boldsymbol{P_i^{sch}}$and $|\boldsymbol{V_i}|$ are specified in (3.6), first (3.11) is solved for $\boldsymbol{Q_i^{(k+1)}}$, and then is used in (3.9) to solve for $\boldsymbol{V_i^{(k+1)}}$. However, since $|\boldsymbol{V_i}|$ is specified, only the imaginary part of $\boldsymbol{V_i^{(k+1)}}$ is retained, and its real part is selected in order to satisfy following equation

$$(\boldsymbol{e_i^{(k+1)}})^{\boldsymbol{2}} + (\boldsymbol{f_i^{(k+1)}})^2 = |\boldsymbol{V_i}|^2 \qquad (3.12)$$

$$\boldsymbol{e_i^{(k+1)}} = \sqrt{|\boldsymbol{V_i}|^2 - \left(\boldsymbol{f_i^{(k+1)}}\right)^{\boldsymbol{2}}} \qquad (3.13)$$

Where $\boldsymbol{e_i^{(k+1)}}$ and $\boldsymbol{f_i^{(k+1)}}$ are the real and imaginary components of the voltage $\boldsymbol{V_i^{(k+1)}}$ in the iterative sequence.

The rate of convergence is increased by applying an acceleration factor to the approximate solution obtained from each iteration.

$$\boldsymbol{V_i^{(k+1)}} = \boldsymbol{V_i^k} + \boldsymbol{\alpha}\left(\boldsymbol{V_{i\,cal}^{(k)}} - \boldsymbol{V_i^{(k)}}\right) \qquad (3.14)$$

Where $\boldsymbol{\alpha}$ is the accelerating factor its value depends upon the system. The range of 1.3 to 1.7 is found to be satisfactory for typical systems.

The updated voltages immediately replace the previous values in the solution of the subsequent equations. The process is continued until changes in the real and imaginary components of bus voltages between successive iterations are within a specified accuracy.

$$|\boldsymbol{e_i^{(k+1)}} - \boldsymbol{e_i^k}| \leq \in$$

$$|\boldsymbol{f_i^{(k+1)}} - \boldsymbol{f_i^k}| \leq \in \qquad (3.15)$$

For the power mismatch to be reasonably small and acceptable, a very tight tolerance must be specified on both components of the voltage .A voltage accuracy in the range of 0.00001 to 0.00005pu is satisfactory .in practice , the method for determining the completion of a solution is based on an accuracy index set up on the power mismatch. This is continued until the magnitude of the largest element the $\Delta\boldsymbol{P}$ and ΔQ columns are less than the specified value. A typical power mismatch accuracy is 0.001pu Once a solution is converged, the net real and reactive powers at the slack bus are computed form (3.10) and (3.11).

3.4 Line flows and losses:

After iterative solution of the bus voltage, the next step is the line flows and line losses, considering two buses $\boldsymbol{i}$ and $\boldsymbol{j}$, where the current is $\boldsymbol{I_{ij}}$, measured at bus $\boldsymbol{i}$ and defined positive in the direction $\boldsymbol{i} \rightarrow \boldsymbol{j}$ is given by

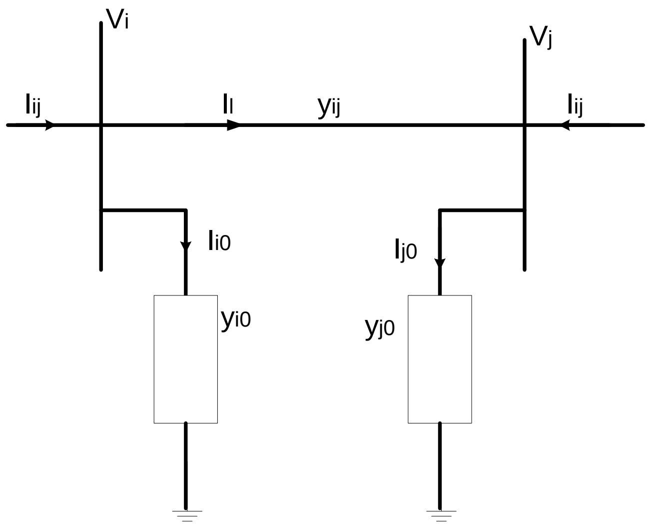


Figure (3.2)

$$\boldsymbol{I_{ij}} = \boldsymbol{I_l} + \boldsymbol{I_{i0}} = \boldsymbol{y_{ij}}(\boldsymbol{V_i} - \boldsymbol{V_j}) + \boldsymbol{y_{i0}}\boldsymbol{V_i} \qquad (3.16)$$

The power loss in line $\boldsymbol{i} - \boldsymbol{j}$ is the algebraic sum of the power flow obtain by (3.18) and (3.19), i.e.,

$$\boldsymbol{S_{L\ ij}} = \boldsymbol{S_{ij}} + \boldsymbol{S_{ji}} \quad (3.17)$$

$$\boldsymbol{I_{ij}} = -\boldsymbol{I_l} + \boldsymbol{I_{i0}} = \boldsymbol{y_{ij}}(\boldsymbol{V_j} - \boldsymbol{V_i}) + \boldsymbol{y_{j0}}\boldsymbol{V_j} \quad (3.18)$$

The complex powers $\boldsymbol{S_{ij}}$ from the $\boldsymbol{i}$ to j and $\boldsymbol{S_{ji}}$ from bus j to $\boldsymbol{i}$ are

$$\boldsymbol{S_{ij}} = \boldsymbol{V_i}\boldsymbol{I_{ij}^*} \quad (3.19)$$

$$\boldsymbol{S_{ji}} = \boldsymbol{V_j}\boldsymbol{I_{ji}^*} \quad (3.20)$$

Example 3.1:

The one line diagram of a simple three bus power system with generators 1 and 3 is shown in the figure (3.3). The magnitude of voltage at bus 1 is adjusted to 1.05pu. Voltage magnitude at bus 3 is fixed at 1.04pu with a real power generation of 200 MW. A load consisting of 400 MW and 250Mvar is taken from bus 2. Line impedances are marked in per unit on a 100MVA base, and the line charging susceptances are neglected. Obtain the power flow solution by the Gauss-Seidel method including line flows and line losses.

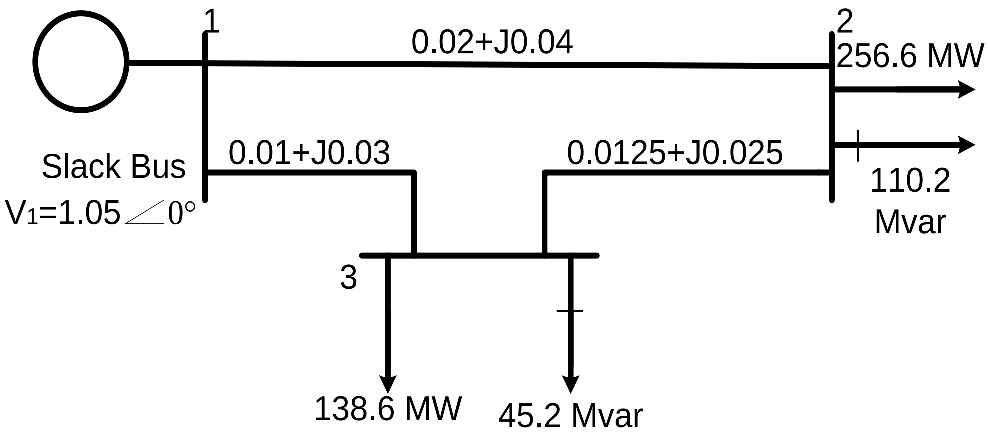


Figure (3.3)

Line impedance is converted to admittances are $\boldsymbol{y_{12} = 10 - j20}$, $\boldsymbol{y_{13} = 10 - j30}$ and $\boldsymbol{y_{23} = 16 - j32}$ the load and generation expressed in per unit.

$$\boldsymbol{S_2^{sch} = -\frac{(400 - j250)}{100} = -4.0 - j2.5 \qquad pu}$$

$$P_3^{sch} = \frac{\mathbf{200}}{\mathbf{100}} = \mathbf{2.0} \qquad pu$$

Bus 1 is taken as the reference bus (slack bus). Starting from an initial estimate of $V_2^{(0)} = \mathbf{1.0} + j\mathbf{0.0}$ and $V_3^{(0)} = \mathbf{1.04} + j\mathbf{0.0}$, V_2 and V_3 are computed from (3.7).

$$V_2^{(1)} = \frac{\frac{P_2^{sch} - jQ_2^{sch}}{V_2^{*(0)}} + y_{12}V_{1+}y_{23}V_3^{(0)}}{y_{12} + y_{23}}$$

$$= \frac{\frac{-4.0 + j2.5}{1.0 - j0} + (10 - j20)(1.05 + j0) + (16 - j32)(1.04 + j0)}{(26 - j52)}$$

$$= 0.97462 - j0.04237$$

Bus 3 is a regulated bus where voltage magnitude and real power are specified. For the voltage – controlled bus, first the reactive power is computed from (3.8)

$$Q_3^{(1)} = -\Im\{V_3^{*(0)}[V_3^{(0)}(y_{13}+y_{23}) - y_{13}V_1 - y_{23}V_2^{(1)}]\}$$

$$= -\Im\{(1.04 - j0)[(1.04 + j0)(26 - j62) - (10 - j30)(1.05 + j0) - (16 - j32)(0.97462 - j0.042307)]\} = 1.16$$

The value of $Q_3^{(1)}$ is used as Q_3^{sch} for the computation of voltage at bus 3. The complex voltage at bus 3, by$V_{c3}^{(1)}$, is calculated

$$V_{c3}^{(1)} = \frac{\frac{P_3^{sch} - jQ_3^{sch}}{V_3^{*(0)}} + y_{13}V_1 + y_{23}V_2^{1}}{y_{13}+y_{23}}$$

$$= ((\mathbf{2.0 - j1.16})/(\mathbf{1.04 - j0}) + (\mathbf{10 - j30})(\mathbf{1.05 + j0}) + (\mathbf{16 - j32})(\mathbf{0.97462} \\ \mathbf{- j0.042307}))/((\mathbf{26 - j62}))$$

$$= \mathbf{1.03783 - j0.005170}$$

Since $|\boldsymbol{V_3}|$ is held constant at 1.04pu, only the imaginary part of $\boldsymbol{V_{c3}^{(1)}}$ is retained

$\boldsymbol{f_3^{(1)}} = \mathbf{-1.005170}$, and its real part is obtained from

$$\boldsymbol{e_3^{(1)}} = \sqrt{(\mathbf{1.04})^2 + (\mathbf{0.005170})^2} = \mathbf{1.039987}$$

Thus

$$\boldsymbol{V_3^{(1)}} = \mathbf{1.039987 - j0.00517}$$

For the second iteration, we have

$$\boldsymbol{V_2^{(2)}} = \frac{\dfrac{\boldsymbol{P_2^{sch} - jQ_2^{sch}}}{\boldsymbol{V_2^{*(1)}}} + \boldsymbol{y_{12}V_1} + \boldsymbol{y_{23}V_3^1}}{\boldsymbol{y_{12}} + \boldsymbol{y_{23}}}$$

$$= ((\mathbf{-4.0 + j2.5})/(\mathbf{0.97462 + j0.42307}) + (\mathbf{10 - j20})(\mathbf{1.05}) + (\mathbf{16 - j32})(\mathbf{1.03987} \\ \mathbf{+ j0.005170}))/((\mathbf{26 - j52}))$$

$$= \mathbf{0.971057 - j0.043432}$$

$$\boldsymbol{Q_3^{(2)}} = -\mathfrak{I}\{\boldsymbol{V_3^{*(1)}}[\boldsymbol{V_3^{(1)}}(\boldsymbol{y_{13}} + \boldsymbol{y_{23}}) - \boldsymbol{y_{13}V_1} - \boldsymbol{y_{23}V_2^{(2)}}]\}$$

$$= -\mathfrak{I}\{(\mathbf{1.039987 + j0.005170})[(\mathbf{1.039987 - j0.005170})(\mathbf{26 - j62}) \\ - (\mathbf{10 - j30})(\mathbf{1.05 + j0}) - (\mathbf{16 - j32})(\mathbf{0.971057 - j0.0434332})]\}$$

$$= \mathbf{1.38796}$$

$$V_{c3}^{(2)} = ((2.0 - j1.38796)/(1.039987 + j0.00517) + (10 + j30)(1.05) + (16 - j32)(0.971057 - j0.04342))/((26 - j62))$$

$$= 1.03908 - j0.00730$$

Since $|V_3|$ is held constant at 1.04pu, only the imaginary part of $V_{c3}^{(2)}$ is retained $f_3^{(2)} = -0.00730$, and its real part is obtained from

$$e_3^{(2)} = \sqrt{(1.04)^2 - (0.00730)^2} = 1.039974$$

Or

$$V_3^{(2)} = 1.039974 - j0.00730$$

The process is continued and a solution is converged with an accuracy of $5 * 10^{-5} pu$ in seven iterations as given below

$$V_2^{(3)} = 0.97073 - j0.04479 \qquad Q_3^{(3)} = 1.42904 \qquad V_3^{(3)} = 1.03996 - j0.00833$$

$$V_2^{(4)} = 0.97065 - j0.04533 \qquad Q_3^{(4)} = 1.44833 \qquad V_3^{(4)} = 1.03996 - j0.00873$$

$$V_2^{(5)} = 0.97062 - j0.04555 \qquad Q_3^{(5)} = 1.45621 \qquad V_3^{(5)} = 1.03996 - j0.00893$$

$$V_2^{(6)} = 0.97061 - j0.04565 \qquad Q_3^{(6)} = 1.45947 \qquad V_3^{(6)} = 1.03996 - j0.00900$$

$$V_2^{(7)} = 0.97061 - j0.04569 \qquad Q_3^{(7)} = 1.46082 \qquad V_3^{(7)} = 1.03996 - j0.00903$$

The final solution is

$$V_2 = 0.97168\angle -2.6948° \quad pu$$

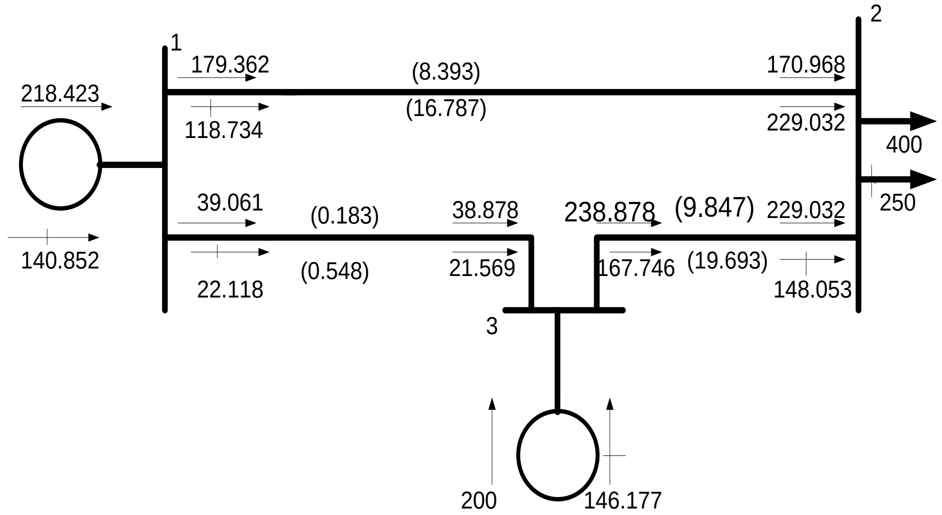
$$S_2 = 2.0 + j1.4617 \quad pu$$

$$V_3 = 1.04\angle -0.498° \quad pu$$

$$S_1 = 2.1842 + j1.4085 \quad pu$$

The result of line flow in MW and line losses in Mvar is:

The power flow diagram is shown below where the real power direction is indicated by → and reactive power direction is indicated by ↦ .The values with parentheses are the real and reactive losses in the line.



figure(3.4)

iter	V2	DV2	Q3	Vc3	V3	DV3
1	0.9746-0.0423i	-0.0254-0.0423i	1.1600	1.0378 - 0.0052i	1.0400-0.0052i	-0.0000-0.0052i
2	0.9711-0.0434i	-0.0036-0.0011i	1.3880	1.0391-0.0073i	1.0400-0.0073i	-0.0000-0.0021i
3	0.9707-0.0448i	-0.0003-0.0014i	1.4290	1.0395 - 0.0083i	1.0400-0.0083i	-0.0000-0.0010i
4	0.9707-0.0453i	-8.1271e-005-5.3820e-004i	1.4483	1.0398 - 0.0088i	1.0400-0.0088i	-3.5058e-006-4.2700e-004i
5	0.9706-0.0456i	-2.8782e-005 - 2.2432e-004i	1.4562	1.0399 - 0.0089i	1.0400-0.0089i	-1.5047e-006-1.7701e-004i
6	0.9706 - 0.0456i	-1.1618e-005 - 9.2700e-005i	1.4595	1.0399 - 0.0090i	1.0400 - 0.0090i	-6.3119e-007 - 7.3214e-005i
7	0.9706 - 0.0457i	-4.7836e-006 - 3.8337e-005i	1.4608	1.0399 - 0.0090i	1.0400 - 0.0090i	-2.6256e-007 - 3.0281e-005i
8	0.9706 - 0.0457i	-1.9772e-006 - 1.5855e-005i	1.4614	1.0400 - 0.0090i	1.0400 - 0.0090i	-1.0886e-007-1.2525e-005i
9	0.9706 0.0457i	-8.1775e-007 - 6.5578e-006i	1.4616	1.0400 - 0.0091i	1.0400 - 0.0091i	-4.5070e-008 - 5.1804e-006i

10	0.9706 - 0.0457i	-3.3824e-007 - 2.7125e-006i	1.4617	1.0400 - 0.0091i	1.0400 - 0.0091i	-1.8650e-008 - 2.1428e-006i

Current output data table

I1221	1.7082 - 1.1308i -1.7082 +1.1308i
I1331	0.3720 - 0.2107i -0.3720 +0.2107i
I2332	-2.2828 + 1.6329i 2.2828 -1.6329i

Complex power data output

S1221	Columns 1 through 3 1.7936 + 1.1874i -1.7096 - 1.0195i 2.1841 + 1.4085i Column 4 0.0839 + 0.1679i
S1331	Columns 1 through 3 0.3906 + 0.2212i -0.3887 - 0.2157i 2.0000 + 1.4618i Column 4 0.0018 + 0.0055i
S2332	Columns 1 through 3 -2.2903 - 1.4805i 2.3888 + 1.6775i -3.9999 - 2.5000i Column 4 0.0985 + 0.1969i

3.5 Tap changing transformer

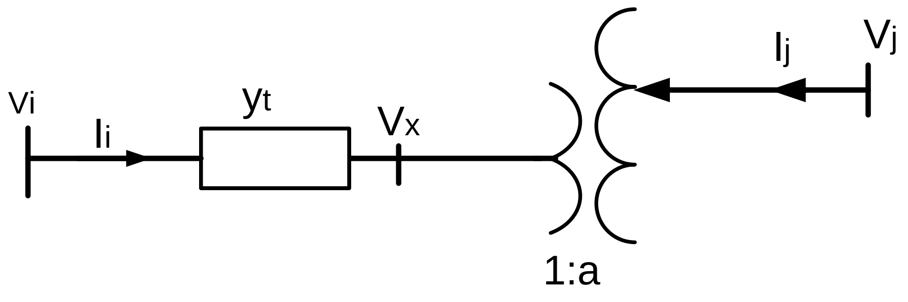
In tap changing transformer, when the ratio is at nominal value, the transformer is represented by a series of admittance $\boldsymbol{y_t}$ in per unit. With off-nominal ratio, the per unit admittance is different from both sides of the transformer, and the admittance must be modified to include the effect of the off-nominal ratio. Consider a transformer with admittance $\boldsymbol{y_t}$ in series with an ideal transformer representing the off-nominal tap ratio 1: $\boldsymbol{a}$ as shown in the figure (3.5).$\boldsymbol{y_t}$ is the admittance per unit based on the nominal turn ratio and $\boldsymbol{a}$ is the per unit off-nominal tap position allowing for small adjustment in voltage of usually $\pm\mathbf{10}$ percent . In the case of phase shifting transformers, $\boldsymbol{a}$ is a complex number .consider a fictitious bus x between the turn ratio and admittance of the transformer. Since the complex power on either side if the ideal transformer is the same, it follows that if the voltage goes through a positive phase angle shift, the current will go through a negative phase angle shift. Thus, for the assumed direction of currents, we have

$$\boldsymbol{V_x} = \frac{\mathbf{1}}{\boldsymbol{a}}\boldsymbol{V_j} \qquad \mathbf{3.21}$$

$$\boldsymbol{I_i} = -\boldsymbol{a}^*\boldsymbol{I_j} \qquad \mathbf{3.22}$$

The current $\boldsymbol{I_i}$ is given by

$$\boldsymbol{I_i} = \boldsymbol{y_t}(\boldsymbol{V_i} - \boldsymbol{V_x})$$



Figure(3.5)

Substituting for $\boldsymbol{V_x}$ we have

$$\boldsymbol{I_i = y_t V_i - \frac{y_t}{a} V_j} \qquad (\mathbf{3.23})$$

Also, from (3.22) we have

$$\boldsymbol{I_j = -\frac{1}{a^*} I_i}$$

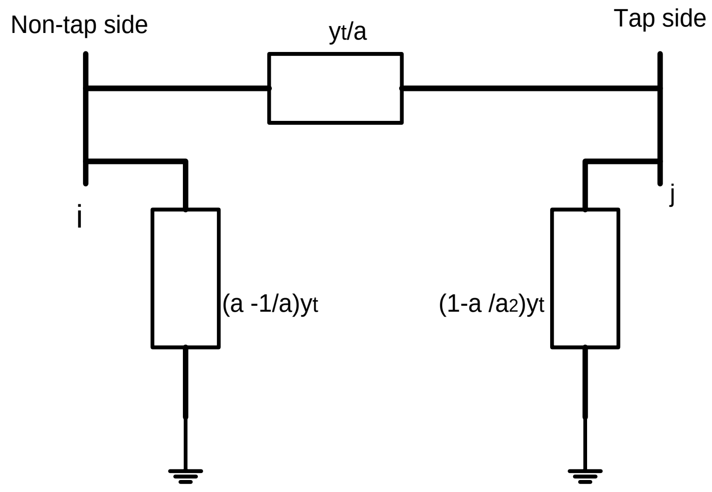
Substituting for $\boldsymbol{I_i}$ from (3.23) we have

$$\boldsymbol{I_j = -\frac{y_t}{a^*} V_i + \frac{y_t}{|V|^2} V_j} \qquad (\mathbf{3.24})$$

Writing (3.23)and (3.24) in matrix form results in

$$\begin{bmatrix} \boldsymbol{I_i} \\ \boldsymbol{I_j} \end{bmatrix} = \begin{bmatrix} \boldsymbol{y_t} & \boldsymbol{-\frac{y_t}{a}} \\ \boldsymbol{\frac{y_t}{y^*}} & \boldsymbol{\frac{y_t}{|a|^2}} \end{bmatrix} \begin{bmatrix} \boldsymbol{V_i} \\ \boldsymbol{V_j} \end{bmatrix} \qquad (\mathbf{3.25})$$

In this case if the a is real ,the $\boldsymbol{\pi}$ model shown in the figure represents the admittance matrix in(3.25).in the $\boldsymbol{\pi}$ model, the left side corresponds to the non-tap side and the right side corresponding to the tap side of the transformer .



Figure(3.6)

Matlab program for the chapter 3 examples

Example (3.1)

```
%Example 3.1

y12=10-j*20;
y13=10-j*30;
y23=16-j*32;
y33=y13+y23;
V1=1.05+j*0;
%format long
iter =0;
S2=-4.0-j*2.5;
P3 = 2;
V2=1+j*0;
Vm3=1.04;
V3=1.04+j*0;
for I=1:10;
iter=iter+1      %NO of iteration
E2 = V2;
E3=V3;
V2= (conj(S2)/conj(V2)+y12*V1+y23*V3)/(y12+y23)
DV2 = V2-E2
Q3 = -imag(conj(V3)*(y33*V3-y13*V1-y23*V2))
S3 = P3 +j*Q3;
Vc3= (conj(S3)/conj(V3)+y13*V1+y23*V2)/(y13+y23)
Vi3 = imag(Vc3);
Vr3= sqrt(Vm3^2 - Vi3^2);
V3 = Vr3 + j*Vi3
DV3=V3-E3
end
format short
```

```
%consideration of currents
I12=y12*(V1-V2); I21=-I12;
I13=y13*(V1-V3); I31=-I13;
I23=y23*(V2-V3); I32=-I23;
%consideration of complex powers
S12=V1*conj(I12); S21=V2*conj(I21);
S13=V1*conj(I13); S31=V3*conj(I31);
S23=V2*conj(I23); S32=V3*conj(I32);
I1221=[I12,I21]
I1331=[I13,I31]
I2332=[I23,I32]
S1221=[S12, S21  (S12+S13) S12+S21]
S1331=[S13, S31  (S31+S32) S13+S31]
S2332=[S23, S32  (S23+S21) S23+S32]
```

CHAPTER 4

4.1 Power Flow Program

Several computer programs have been developed for the power flow solution of practical systems. Each method of solution consists of four programs. The program for the gauss-seidel method is Lfgauss, which is preceded by Lfybus, and is followed by busout and lineflow. Programs Ifybus ,busout,and lineflow are designed to be used with two more power flow programs. These are Lfnewton for the Newton-Raphson method and decouple for fast decouple method. The following is a brief description of the programs used in the gauss-Seidel method.

4.1.1 Lfybus

This program is requires the line and transformer parameters and transformer tap settings specified in the input file named linedata. It converting impedances to admittances and obtains the bus admittance matrix. The program is designed to handle parallel lines.

4.1.2 Lfgauss

This program is obtains the power flow solution by the Gauss-Seidel method and requires the files named busdata and linedata. It designed for the direct use of load and generation in MW and Mvar, bus voltages in per unit, and angle in degrees. Loads and generation are converted to per unit quantities on the base MVA selected. A provision is made to maintain the generator reactive power of the voltage controlled buses within their specified limits. The violation of reactive

Power limit may occur if the specified voltage is either too high or too low. After a few iterations (10th iteration in the Gauss metod), the var calculated at the generator buses are examined. If a limit is reached, the voltage magnitude is adjusted in steps of 0.5 percent up to $\pm\mathbf{5}$ percent to bring the var demand within the specified limites.

4.1.3 Busout

This program produces the bus output result in tabulated form. The bus output result includes the voltage magnitude and angle, real and reactive power of generators and loads, and the shunt capacitor/reactors M var. Total generation and total load are also outlined in the sample case.

4.1.4 Lineflow

this program prepares the line output data. It is design to display the active and reactive power flow entering the line terminals and line losses as well as the net power at each bus. Also included are the total real and reactive losses in the system. The output of this portion is also shown in the sample case.

4.2 Data preparation

In order to perform the power flow analysis in matlab environment, we need to define the following variables, power system base MVA, power mismatch accuracy, acceleration factor, and maximum number of iterations. The name (in lowercases latters) reserved for these variables are base mva , accuracy, accel, and maxiter , respectively. The typical values are as follows:

basemva=100;

accuracy= 0.001;

accel=1.8;

maxiter=100;

which the following data file are required.

4.2.1 Bus Data file-busdata

The format for the bus entry is chosen to facilitate the require data for each bus in single row. The information required must be included in a matrix called busdata. Column 1 is the bus number, column 2 contains the bus code, column 4 and 5 are the voltage magnitude in per unit and phase angle in degrees. Column 5 and 6 are load MW and Mvar. Columns 7 through 10 are MW, Mvar, minimum Mvar and maximum Mvar of generator, in that order.

The last column is the injected Mvar of shunt capacitors. The bus code entered in column 2 is used for identifying load, voltage-controlled, and slack buses as outlined below:

1 this code is used for the slack bus. The only necessary information for this bus is the voltage magnitude and its phase angle.

0 this code is using for load buses. The load is entered positive in megawatts and megavars. For this bus the initial estimate must be specified. This is usually 1 and 0for voltage magnitude and phase angle for this type of bus are specified.

they will be taken as the initial starting voltage for that bus instead of a flat start of 1 and 0.

2 this code is used for voltage controlled buses. For this bus the voltage magnitude and real power generation in megawatts, and the minimum and maximum limits of the megavar demand must be specified

4.2.2 Line Data file - linedata

Lines are identified by the node-pair method. The information required must be included in a matrix called linedata. Columns 1 and 2 are the line bus numbers. Column 3 through 5 contains the line resistance, reactance and half of the total line charging susceptance in per unit on the specified MVA base. The last column is for the transformer tap setting for lines, 1 must be entered in any sequence or order with the only restriction being that if the entry is a transformer, the left bus number is assumed to be the tap side of the transformer.

The IEEE 30 bus system is used to demonstrate the data reparation and the use of the power flow programs by the Gauss-Seidel method.

Example 4.1:

In figure (4.1) is part of the American Electric power service Corporation network which is being made available to the electric utility industry as a standard test case for evaluation various analytical methods and computer programs for the solution of power system problems. Use the Ifgauss program to obtain the power solution by the Gauss-Seidel method. Bus 1 is taken as the slack bus with its voltage adjusted to $1.06\angle\mathbf{0}°\ \boldsymbol{pu}$. The data for the voltage-controlled buses is

Regulated Bus Data

bus No	Voltage magnitude	min Mvar capacity	Max.Mvar capacity
2	1.043	-40	50
5	1.010	-40	40
8	1.010	-10	0
11	1.082	-6	24
13	1.071	-6	24

Transformer tap setting is given in the table below. The left bus number is

Summed to be the tap side of the transformer.

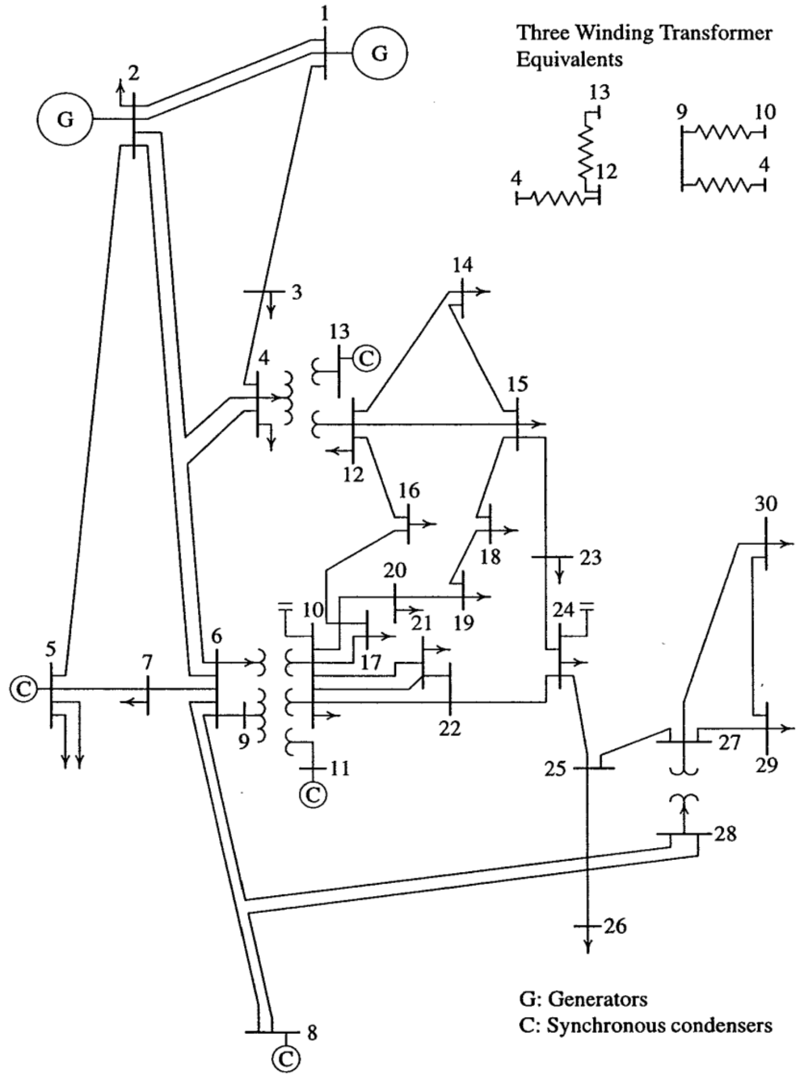
Transformer Data

Transformer designation	Tap setting pu
4-12	0.932
6-9	0.978
6-10	0.969
28-27	0.968

The data for the injected Q due to shunt capacitors is

Injected Q due to capacitors

Bus No.	Mvar
10	19
24	4.3


Three Winding Transformer
Equivalents
13
12
4
9
10
4
1
2
G
G
3
4
13
12
14
15
16
18
23
30
20
19
10
21
17
24
22
6
5
7
9
11
25
27
29
28
26
8
G: Generators
C: Synchronous condensers

Figure(4.1)

Generation and loads are as given in the data prepared for use in the matlab environment in the matrix defined as busdata. Code 0, code 1, and code 2 are used for the load buses, the slack bus and the voltage controlled buses, respectively. Values for basemva, accuracy, accel and maxiter must be specified. Line data are as given in the matrix called linedata. The last column of this data must contain 1 for lines, or the tap setting values for transformers with off-nominal turn ratio. The control commands required are Ifybus, Ifgauss and lineflow. A diary command may be used to save the output to the specified file name. The power flow data and the commands required are as follows.

```
%calculation of 30 bus system
clear all;   %clears all the variables from workspace.
basemva=100;
accuracy=0.001;
accel=1.8;
maxiter=100;
%   IEEE 30-BUS TEST SYSTEM (American Electric power)
%    Bus Bus Voltage  Angle ---Load--    ---Generator--------Injected
%No code Mag. Degree Mw    Mvar     MW  Mvar Qmin  Qmax  Mvar
busdata=[
1   1    1.06    0.0     0.0   0.0    0.0  0.0   0   0      0
2   2    1.043   0.0   21.70  12.7   40.0  0.0 -40  50      0
3   0    1.0     0.0     2.4   1.2    0.0  0.0   0   0      0
4   0    1.06    0.0     7.6   1.6    0.0  0.0   0   0      0
5   2    1.01    0.0    94.2  19.0    0.0  0.0 -40  40      0
6   0    1.0     0.0     0.0   0.0    0.0  0.0   0   0      0
7   0    1.0     0.0    22.8  10.9    0.0  0.0   0   0      0
```

8	2	1.01	0.0	30.0	30.0	0.0	0.0	-30	40	0
9	0	1.0	0.0	0.0	0.0	0.0	0.0	0	0	0
10	0	1.0	0.0	5.8	2.0	0.0	0.0	-6	24	19
11	2	1.082	0.0	0.0	0.0	0.0	0.0	0	0	0
12	0	1.0	0	11.2	7.5	0	0	0	0	0
13	2	1.071	0	0	0.0	0	0	-6	24	0
14	0	1	0	6.2	1.6	0	0	0	0	0
15	0	1	0	8.2	2.5	0	0	0	0	0
16	0	1	0	3.5	1.8	0	0	0	0	0
17	0	1	0	9.0	5.8	0	0	0	0	0
18	0	1	0	3.2	0.9	0	0	0	0	0
19	0	1	0	9.5	3.4	0	0	0	0	0
20	0	1	0	2.2	0.7	0	0	0	0	0
21	0	1	0	17.5	11.2	0	0	0	0	0
22	0	1	0	0	0.0	0	0	0	0	0
23	0	1	0	3.2	1.6	0	0	0	0	0
24	0	1	0	8.7	6.7	0	0	0	0	4.3
25	0	1	0	0	0.0	0	0	0	0	0
26	0	1	0	3.5	2.3	0	0	0	0	0
27	0	1	0	0	0.0	0	0	0	0	0
28	0	1	0	0	0.0	0	0	0	0	0

```
29   0   1     0     2.4   0.9   0   0    0   0     0
30   0   1     0    10.6   1.9   0   0    0   0     0];
% Line Data
%
%   Bus    bus     R     x       1/2 B  1 for Line code or
%   n1     nr     pu    pu        pu     tap setting value
linedata=[
1    2    0.0192    0.0575    0.02640     1
1    3    0.0452    0.1852    0.02040     1
2    4    0.0570    0.1737    0.01840     1
3    4    0.0132    0.0379    0.00420     1
2    5    0.0472    0.1983    0.02090     1
2    6    0.0581    0.1763    0.01870     1
4    6    0.0119    0.0414    0.00450     1
5    7    0.0460    0.1160    0.01020     1
6    7    0.0267    0.0820    0.00850     1
6    8    0.0120    0.0420    0.00450     1
6    9    0.0        0.2080    0.0          0.978
6    10   0.0        0.5560    0.0          0.969
9    11   0.0        0.2080    0.0          1
9    10   0.0        0.1100    0.0          1
```

4	12	0.0	0.2560	0.0	0.932
12	13	0.0	0.1400	0.0	1
12	14	0.1231	0.2559	0.0	1
12	15	0.0662	0.1304	0.0	1
12	16	0.0945	0.1987	0.0	1
14	15	0.2210	0.1997	0.0	1
16	17	0.0824	0.1923	0.0	1
15	18	0.1073	0.2185	0.0	1
18	19	0.0639	0.1292	0.0	1
19	20	0.0340	0.0680	0.0	1
10	20	0.0936	0.2090	0.0	1
10	17	0.0324	0.0845	0.0	1
10	21	0.0348	0.0749	0.0	1
10	22	0.0727	0.1499	0.0	1
21	22	0.0116	0.0236	0.0	1
15	23	0.1000	0.2020	0.0	1
22	24	0.1150	0.1790	0.0	1
23	24	0.1320	0.2700	0.0	1
24	25	0.1885	0.3292	0.0	1
25	26	0.2544	0.3800	0.0	1
25	27	0.1093	0.2087	0.0	1

```
28   27   0.0000  0.3960   0.0      0.968
27   29   0.2198  0.4153   0.0      1
27   30   0.3202  0.6027   0.0      1
29   30   0.2399  0.4533   0.0      1
8    28   0.0636  0.2000   0.0214   1
6    28   0.0169  0.0599   0.065    1];
%
lfybus       %Forms the bus admittance matrix
lfgauss      %Power flow solution by Gauss-Seidel method
busout       %Prints the power flow solution on the screen
lineflow     %Computes and displays the line flow and losses
```

The Ifgauss, busout and the lineflow produce the following tabulated results.

Power Flow Solution by Gauss-Seidel Method

Maximum Power Mismatch = 0.000951884

```
Bus  Voltage  Angle    ------Load------   ---Generation---   Injected
No.  Mag.     Degree   MW       Mvar      MW       Mvar      Mvar
```

No. of Iterations = 34

No.	*mag.*	*Degree*	*MW*	*Mvar*	*MW*	*Mvar*	*Mvar*
1	*1.060*	*0.000*	*0.000*	*0.000*	*260.950*	*-17.010*	*0.000*
2	*1.043*	*-5.496*	*21.700*	*12.700*	*40.000*	*48.826*	*0.000*
3	*1.022*	*-8.002*	*2.400*	*1.200*	*0.000*	*0.000*	*0.000*
4	*1.013*	*-9.659*	*7.600*	*1.600*	*0.000*	*0.000*	*0.000*
5	*1.010*	*-14.380*	*94.200*	*19.000*	*0.000*	*35.995*	*0.000*
6	*1.012*	*-11.396*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
7	*1003*	*-13.149*	*22.800*	*10.900*	*0.000*	*0.000*	*0.000*
8	*1.010*	*-12.114*	*30.000*	*30.000*	*0.000*	*30.759*	*0.000*
9	*1.051*	*-14.432*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
10	*1.044*	*-16.024*	*5.800*	*2.000*	*0.000*	*0.000*	*19.000*
11	*1.082*	*-14.432*	*0.000*	*0.000*	*0.000*	*6.113*	*0.000*
12	*1.057*	*-15.301*	*11.200*	*7.500*	*0.000*	*0.000*	*0.000*
13	*1.071*	*-15.300*	*0.000*	*0.000*	*0.000*	*10.379*	*0.000*
14	*1.043*	*-16.190*	*6.200*	*1.600*	*0.000*	*0.000*	*0.000*
15	*1.038*	*-16.276*	*8.200*	*2.500*	*0.000*	*0.000*	*0.000*
16	*1.045*	*-15.879*	*3.500*	*1.800*	*0.000*	*0.000*	*0.000*
17	*1.039*	*-16.187*	*9.000*	*5.800*	*0.000*	*0.000*	*0.000*
18	*1.028*	*16.881*	*3.200*	*0.900*	*0.000*	*0.000*	*0.000*
19	*1.025*	*-17.049*	*9.500*	*3.400*	*0.000*	*0.000*	*0.000*

20	*1.029*	*-16.851*	*2.200*	*0.700*	*0.000*	*0.000*	*0.000*
21	*1.032*	*-16.468*	*17.500*	*11.200*	*0.000*	*0.000*	*0.000*
22	*1.033*	*-16.455*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
23	*1.027*	*-16.660*	*3.200*	*1.600*	*0.000*	*0.000*	*0.000*
24	*1.022*	*16.829*	*8.700*	*6.700*	*0.000*	*0.000*	*4.300*
25	*1.019*	*-16.423*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
26	*1.001*	*-16.835*	*3.500*	*2.300*	*0.000*	*0.000*	*0.000*
27	*1.026*	*-15.913*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
28	*1.011*	*-12.056*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
29	*1.006*	*-17.133*	*2.400*	*0.900*	*0.000*	*0.000*	*0.000*
30	*0.994*	*-18.016*	*10.600*	*1.900*	*0.000*	*0.000*	*0.000*
Total			*283.400*	*126.200*	*0.950*	*125.089*	*23.300*

Line Flow and Losses

--Line--		Power at bus & line flow			--Line loss--		Transformer
from	to	MW	Mvar	MVA	MW	Mvar	tap
1		260.950	-17.010	261.504			
	2	177.743	-22.140	179.117	5.461	10.517	
	3	83.197	5.125	83.354	2.807	7.079	
2		18.300	36.126	40.497			
	1	-172.282	32.657	175.350	5.461	10.517	
	4	45.702	2.720	45.783	1.106	-0.519	
	5	82.990	1.704	83.008	2.995	8.178	
	6	61.905	-0.966	61.913	2.047	2.263	
3		-2.400	-1.200	2.683			
	1	-80.390	1.954	80.414	2.807	7.079	
	4	78.034	-3.087	78.095	0.771	1.345	
4		-7.600	-1.600	7.767			
	2	-44.596	-3.239	44.713	1.106	-0.519	

3 -77.263 4.432 77.390 0.771 1.345

6 70.132 -17.624 72.313 0.605 1.181

12 44.131 14.627 46.492 0.000 4.686 0.932

5 -94.200 16.995 95.721

2 -79.995 6.474 80.256 2.995 8.178

7 -14.210 10.467 17.649 0.151 -1.687

6 0.000 0.000 0.000

2 -59.858 3.229 59.945 2.047 2.263

4 -69.527 18.805 72.026 0.605 1.181

7 37.537 -1.915 37.586 0.368 -0.598

8 29.534 -3.712 29.766 0.103 -0.558

9 27.687 -7.318 28.638 0.000 1.593 0.978

10 15.828 0.656 15.842 -0.000 1.279 0.969

28 18.840 -9.575 21.134 0.060 -13.085

7 -22.800 -10.900 25.272

5 14.361 -12.154 18.814 0.151

6 -37.170 1.317 37.193 0.368 -0.598

8 -30.000 0.759 30.010

6 -29.431 3.154 29.599 0.103 -0.558

28	-0.570	-2.366	2.433	0.000	-4.368
	9	0.000	0.000	0.000	
6	-27.687	8.911	29.086	0.000	1.593
11	0.003	-15.653	15.653	0.000	0.461
10	27.731	6.747	28.540	-0.000	0.811
	10	-5.800	17.000	17.962	
6	-15.828	0.623	15.840	-0.000	1.279
9	-27.731	-5.936	28.359	-0.000	0.811
20	9.018	3.569	9.698	0.081	0.180
17	5.347	4.393	6.920	0.014	0.037
21	15.723	9.846	18.551	0.110	0.236
22	7.582	4.487	8.811	0.052	0.107
	11	0.000	16.113	16.113	
9	-0.003	16.114	16.114	0.000	0.461
	12	-11.200	-7.500	13.479	
4	-44.131	-9.941	45.237	0.000	4.686

13	-0.021	-10.274	10.274	0.000	0.132
14	7.852	2.428	8.219	0.074	0.155
15	17.852	6.968	19.164	0.217	0.428
16	7.206	3.370	7.955	0.053	0.112
13		0.000	10.406	10.406	
12	0.021	10.406	10.406	0.000	0.132
14		-6.200	-1.600	6.403	
12	-7.778	-2.273	8.103	0.074	0.155
15	1.592	0.708	1.742	0.006	0.006
15		-8.200	-2.500	8.573	
12	-17.634	-6.540	18.808	0.217	0.428
14	-1.586	-0.702	1.734	0.006	0.006
18	6.009	1.741	6.256	0.039	0.079
23	5.004	2.963	5.815	0.031	0.063
16		-3.500	-1.800	3.936	
12	-7.152	-3.257	7.859	0.053	0.112
17	3.658	1.440	3.931	0.012	0.027
17		-9.000	-5.800	10.707	
16	-3.646	-1.413	3.910	0.012	0.027
10	-5.332	-4.355	6.885	0.014	0.037
18		-3.200	-0.900	3.324	
15	-5.970	-1.661	6.197	0.039	0.079

19	2.779	0.787	2.888	0.005	0.010
19		-9.500	-3.400	10.090	
18	-2.774	-0.777	2.881	0.005	0.010
20	-6.703	-2.675	7.217	0.017	0.034
20		-2.200	-0.700	2.309	
19	6.720	2.709	7.245	0.017	0.034
10	-8.937	-3.389	9.558	0.081	0 .180
21		-17.500	-11.200	20.777	
10	-15.613	-9.609	18.333	0.110	0.236
22	-1.849	-1.627	2.463	0.001	0.001
22		0.000	0.000	0.000	
10	-7.531	-4.380	8.712	0.052	0.107
21	1.850	1.628	2.464	0.001	0.001
24	5.643	2.795	6.297	0.043	0.067
23		-3.200	-1.600	3.578	
15	-4.972	-2.900	5.756	0.031	0.063
24	1.771	1.282	2.186	0.006	0.012
24		-8.700	-2.400	9.025	
22	-5.601	-2.728	6.230	0.043	0.067
23	-1.765	-1.270	2.174	0.006	0.012
25	-1.322	1.604	2.079	0.008	0.014
25		0.000	0.000	0.000	

24	1.330	-1.590	2.073	0.008	0.014	
26	3.520	2.372	4.244	0.044	0.066	
27	-4.866	-0.786	4.929	0.026	0.049	
26		-3.500	-2.300	4.188		
25	-3.476	-2.306	4.171	0.044	0.066	
27		0.000	0.000	0.000		
25	4.892	0.835	4.963	0.026	0.049	
28	-18.192	-4.152	18.660	-0.000	1.310	
29	6.178	1.675	6.401	0.086	0.162	
30	7.093	1.663	7.286	0.162	0.304	
28		0.000	0.000	0.000		
27	18.192	5.463	18.994	-0.000	1.310	0.968
6	-18.780	-3.510	19.106	0.060	-13.085	
29		-2.400	-0.900	2.563		
27	-6.093	-1.513	6.278	0.086	0.162	
30	3.716	0.601	3.764	0.034	0.063	

30		-10.600	-1.900	10.769		
	27	-6.932	-1.359	7.064	0.162	0.304
	29	-3.683	-0.537	3.722	0.034	0.063
Total loss					*17.594*	*22.233*

4.3 NEWTON RAPHSON POWER FLOW SOLUTION

Because of its initial quadratic convergence, Newton's method is mathematically superior to the gauss-Seidel method and is less prone to divergence with ill- conditioned problems. For large power systems, The Newton-Raphson method is found to be more efficient and practical. The number of iteration requires to obtain the solution is independent of the system size, but more functional evaluations are required at each iteration. Since in the power flow problem real power and voltage magnitude are specified for the voltage- controlled buses, the power flow equation is formulated in polar form. For the typical bus of the power system in the figure (6.7), The current entering bus $\boldsymbol{i}$ is given by (3.2). This equation can be rewritten in terms of the bus admittance matrix as

$$\boldsymbol{I_i = \sum_{j=1}^{n} Y_{ij} V_j} \qquad \mathbf{4.1}$$

In the above equation, j includes bus i. Expressing this equation in polar form, we have

$$\boldsymbol{I_i = \sum_{j=1}^{n} |Y_{ij}||V_j| \ \angle\theta_{ij} + \delta_j} \qquad (\mathbf{4.2})$$

The complex power at bus $\boldsymbol{i}$ is

$$\boldsymbol{P_i + jQ_i = V_i^* I_i} \qquad (4.3)$$

Substituting from (4.2) for $\boldsymbol{I_i}$ in (4.3).

$$\boldsymbol{P_i + jQ_i = |V_i|\angle - \delta_i \sum_{j=1}^{n} |Y_{ij}||V_j|\angle\theta_{ij} + \delta_j} \qquad (\mathbf{4.4})$$

Separating the real and imaginary parts,

$$P_i = \sum_{j=1}^{n} |Y_{ij}||V_j||Y_i| \cos(\theta_{ij} - \delta_i + \delta_j) \qquad (4.5)$$

$$Q_i = -\sum_{j=1}^{n} |Y_{ij}||V_j||Y_i| \sin(\theta_{ij} - \delta_i + \delta_j) \qquad (4.6)$$

Equations (4.5) and (4.6) constitute a set of nonlinear algebraic equations in terms of the independent variables, voltage magnitude in per unit, and phase angle in radians. We have two equations for each load bus, given by (4.5) and (4.6), and one equation for each voltage-controlled bus, given by (4.5). expanding (4.5)and(4.6) in Taylor's series about the initial estimate and neglecting all higher order terms results in the following set of linear equations.

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \hline \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \begin{bmatrix} \begin{bmatrix} \frac{\partial P_2^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial P_2^{(k)}}{\partial \delta_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial P_n^{(k)}}{\partial \delta_n} \end{bmatrix} & \begin{bmatrix} \frac{\partial P_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_n^{(k)}}{\partial |V_n|} \end{bmatrix} \\ \begin{bmatrix} \frac{\partial Q_2^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial Q_2^{(k)}}{\partial \delta_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial Q_n^{(k)}}{\partial \delta_n} \end{bmatrix} & \begin{bmatrix} \frac{\partial Q_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_n^{(k)}}{\partial |V_n|} \end{bmatrix} \end{bmatrix} \begin{bmatrix} \Delta \delta_2^{(k)} \\ \vdots \\ \Delta \delta_n^{(k)} \\ \hline \Delta |V_2^{(k)}| \\ \vdots \\ \Delta |V_n^{(k)}| \end{bmatrix} \qquad (4.7)$$

In the above equation, bus 1is assumed to be the slack bus. The Jacobian matrix gives the linearized relationship between small changes in voltage angle $\Delta\delta_i^{(k)}$ and voltage magnitude $\Delta|V_i^{(k)}|$ with the small changes in real and reactive power $\Delta P_i^{(k)}$and $\Delta Q_i^{(k)}$. Elements of the Jacobian matrix are the partial derivatives of (4.5)and(4.6), evaluated at $\Delta\delta_i^{(k)}$ and $\Delta|V_i^{(k)}|$.In short form, it can be written as

$$\begin{bmatrix} \Delta \boldsymbol{P} \\ \Delta \boldsymbol{Q} \end{bmatrix} = \begin{bmatrix} \boldsymbol{J_1} & \boldsymbol{J_2} \\ \boldsymbol{J_3} & \boldsymbol{J_4} \end{bmatrix} \begin{bmatrix} \Delta \boldsymbol{\delta} \\ \Delta |\boldsymbol{V}| \end{bmatrix} \qquad (4.8)$$

For voltage-controlled buses, the voltage magnitudes are known. Therefore, if m buses of the system are voltage-controlled, m equations involving $\Delta \boldsymbol{Q}$ and $\Delta \boldsymbol{V}$ and the corresponding columns of the Jacobian matrix are eliminated. Accordingly, There are n-1 real power constraints and n-1-m reactive power constrains, and the Jacobian matrix is of order (2n-2-m)*(2n-2-m). $\boldsymbol{J_1}$ Is of the order (n-1)*(n-1), $\boldsymbol{J_2}$ is of the order (n-1)*(n-1-m), $\boldsymbol{J_3}$ is of the order (n-1-m)*(n-1), and $\boldsymbol{J_4}$ is of the order (n-1-m)*(n-1-m).

The diagonal and the off-diagonal elements of $\boldsymbol{J_1}$ are

$$\frac{\partial \boldsymbol{P_i}}{\partial \boldsymbol{\delta_i}} = \sum_{j \neq i} |\boldsymbol{V_i}||\boldsymbol{V_j}||\boldsymbol{V_{ij}}| \, \boldsymbol{sin}(\boldsymbol{\theta_{ij}} - \boldsymbol{\delta_i} + \boldsymbol{\delta_j}) \qquad (\boldsymbol{4.9})$$

$$\frac{\partial \boldsymbol{P_i}}{\partial \boldsymbol{\delta_i}} = -|\boldsymbol{V_i}||\boldsymbol{V_j}||\boldsymbol{Y_{ij}}| \, \boldsymbol{sin}(\boldsymbol{\theta_{ij}} - \boldsymbol{\delta_i} + \boldsymbol{\delta_j}) \qquad \boldsymbol{j \neq i} \qquad (\boldsymbol{4.10})$$

The diagonal and off diagonal elements of $\boldsymbol{J_2}$

$$\frac{\partial \boldsymbol{P_i}}{\partial \boldsymbol{V_i}} = \boldsymbol{2}|\boldsymbol{V_i}||\boldsymbol{Y_{ii}}| \sum_{j \neq i} |\boldsymbol{V_j}||\boldsymbol{V_{ij}}| \, \boldsymbol{cos}(\boldsymbol{\theta_{ij}} - \boldsymbol{\delta_i} + \boldsymbol{\delta_j}) \qquad (\boldsymbol{4.11})$$

$$\frac{\partial \boldsymbol{P_i}}{\partial |\boldsymbol{V_j}|} = |\boldsymbol{V_j}||\boldsymbol{Y_{ij}}| \, \boldsymbol{cos}(\boldsymbol{\theta_{ij}} - \boldsymbol{\delta_i} + \boldsymbol{\delta_j}) \qquad \boldsymbol{j \neq i} \qquad (\boldsymbol{4.12})$$

The diagonal and the off diagonal elements of $\boldsymbol{J_3}$

$$\frac{\partial \boldsymbol{Q_i}}{\partial \boldsymbol{\delta_i}} = \sum_{j \neq i} |\boldsymbol{V_i}||\boldsymbol{V_j}||\boldsymbol{V_{ij}}| \, \boldsymbol{cos}(\boldsymbol{\theta_{ij}} - \boldsymbol{\delta_i} + \boldsymbol{\delta_j}) \qquad (\boldsymbol{4.13})$$

$$\frac{\partial \boldsymbol{Q_i}}{\partial \boldsymbol{\delta_j}} = -|\boldsymbol{V_i}||\boldsymbol{V_j}||\boldsymbol{Y_{ij}}| \, \boldsymbol{cos}(\boldsymbol{\theta_{ij}} - \boldsymbol{\delta_i} + \boldsymbol{\delta_j}) \qquad \boldsymbol{j \neq i} \qquad (\boldsymbol{4.14})$$

The diagonal and the off diagonal elements of $\boldsymbol{J_4}$

$$\frac{\partial \boldsymbol{Q_i}}{\partial \boldsymbol{V_i}} = -2|\boldsymbol{V_i}||\boldsymbol{Y_{ii}}|\boldsymbol{sin\theta_{ii}} - \sum_{j\neq i}|\boldsymbol{V_j}||\boldsymbol{V_{ij}}|\,\boldsymbol{sin}(\boldsymbol{\theta_{ij}} - \boldsymbol{\delta_i} + \boldsymbol{\delta_j}) \qquad (\mathbf{4.15})$$

$$\frac{\partial \boldsymbol{Q_i}}{\partial \boldsymbol{\delta_i}} = -|\boldsymbol{V_i}||\boldsymbol{Y_{ij}}|\,\boldsymbol{sin}(\boldsymbol{\theta_{ij}} - \boldsymbol{\delta_i} + \boldsymbol{\delta_j}) \qquad \boldsymbol{j \neq i} \qquad (\mathbf{4.16})$$

The terms $\Delta\boldsymbol{P_i^{(k)}}$ and $\Delta\boldsymbol{Q_i^{(k)}}$ are the difference between the scheduled and calculated values, known as the power residuals, given by

$$\Delta\boldsymbol{P_i^{(k)}} = \boldsymbol{P_i^{sch}} - \boldsymbol{P_i^{(k)}} \qquad (\mathbf{4.17})$$

$$\Delta\boldsymbol{Q_i^{(k)}} = \boldsymbol{Q_i^{sch}} - \boldsymbol{Q_i^{(k)}} \qquad (\mathbf{4.18})$$

The new estimates for bus voltages are

$$\boldsymbol{\delta_i^{(k+1)}} = \boldsymbol{\delta_i^{(k)}} + \Delta\boldsymbol{\delta_i^{(k)}} \qquad (\mathbf{4.19})$$

$$|\boldsymbol{V_i^{(k+1)}}| = |\boldsymbol{V_i^{(k)}}| + \Delta|\boldsymbol{V_i^{(k)}}| \qquad (\mathbf{4.20})$$

Example 4.2:

Obtain the power flow solution for the IEEE-30 bus test system by Newton-Raphson method.

The data required is same as in example (4.1) with the following commands

The output of Lfnewton is

Power Flow Solution by Newton-Raphson Method

Maximum Power Mismatch = 7.54898e-007
No. of Iterations = 4

Bus Voltage Angle ------------------Load------ ----------Generation----- Injected

No.	Mag.	Degree	MW	Mvar	MW	Mvar	Mvar
1	1.060	0.000	0.000	0.000	60.998	-17.021	0.000
2	0.043	-5.497	21.700	12.700	0.000	48.822	0.000
3	1.022	-8.004	2.400	1.200	0.000	0.000	0.000
4	1.013	-9.661	7.600	1.600	0.000	0.000	0.000
5	1.010	-14.381	94.200	19.000	0.000	35.975	0.000
6	1.012	-11.398	0.000	0.000	0.000	0.000	0.000
7	1.003	-13.150	22.800	10.900	0.000	0.000	0.000
8	1.010	-12.115	30.000	0.000	0.000	30.826	0.000
9	1.051	-14.434	0.000	0.000	0.000	0.000	0.000
10	1.044	-16.024	5.800	2.000	0.000	0.000	19.000
11	1.082	-14.434	0.000	0.000	0.000	16.119	0.000
12	1.057	-15.302	11.200	7.500	0.000	0.000	0.000
13	1.071	-15.302	0.000	0.000	0.000	0.423	0.000
14	1.042	-16.191	6.200	1.600	0.000	0.000	0.000
15	1.038	-16.278	8.200	2.500	0.000	0.000	0.000
16	1.045	-15.880	3.500	1.800	0.000	0.000	0.000
17	1.039	-16.188	9.000	5.800	0.000	0.000	0.000
18	1.028	-16.884	3.200	0.900	0.000	0.000	0.000
19	1.025	-17.052	9.500	3.400	0.000	0.000	0.000
20	1.029	-16.852	2.200	0.700	0.000	0.000	0.000
21	1.032	-16.468	17.500	11.200	0.000	0.000	0.000
22	1.033	-16.455	0.000	0.000	0.000	0.000	0.000
23	1.027	-16.662	3.200	1.600	0.000	0.000	0.000
24	1.022	-16.830	8.700	6.700	0.000	0.000	4.300

25	1.019	-16.424	0.000	0.000	0.000	0.000	0.000
26	1.001	-16.842	3.500	2.300	0.000	0.000	0.000
27	1.026	-15.912	0.000	0.000	0.000	0.000	0.000
28	1.011	-12.057	0.000	0.000	0.000	0.000	0.000
29	1.006	-17.136	2.400	0.900	0.000	0.000	0.000
30	0.995	-18.015	0.600	1.900	0.000	0.000	0.000
Total			283.400	126.200	300.998	125.144	23.300

The output of the line flow is the same as the line flow output is

Line Flow and Losses

--Line-- Power at bus & line flow --Line loss-- Transformer

from to MW Mvar MVA MW Mvar tap

1 260.998 -17.021 261.553

2 177.778 -22.148 179.152 5.464 10.524

3 83.221 5.127 83.378 2.808 7.08

2 18.300 36.122 40.493

1 -172.314 32.671 175.384 5.464 10.524

4 45.712 2.705 45.792 1.106 -0.517

5 82.990 1.703 83.008 2.995 8.178

6 61.912 -0.958 61.920 2.048 2.264

3 -2.400 -1.200 2.683

1 -80.412 1.958 80.436 2.808 7.085

4	78.012	-3.158	78.076	0.771	1.344	
4		-7.600	-1.600	7.767		
2	-44.605	-3.222	44.722	1.106	-0.517	
3	-77.242	4.503	77.373	0.771	1.344	
6	70.126	-17.526	72.282	0.604	1.179	
12	44.121	14.646	46.489	0.000	4.685	0.932
5		-94.200	16.975	95.717		
2	-79.995	6.475	80.257	2.995	8.178	
7	-14.205	10.500	17.664	0.151	-1.687	
6		0.000	0.000	0.000		
2	-59.864	3.222	59.951	2.048	2.264	
4	-69.521	18.705	71.994	0.604	1.179	
7	37.523	-1.885	37.570	0.367	-0.598	
8	29.528	-3.754	29.766	0.103	-0.558	
9	27.693	-7.322	28.644	0.000	1.594	0.978
10	15.823	0.653	15.836	0.000	1.278	0.969
28	18.819	-9.618	21.134	0.060	-13.086	
7		-22.800	-10.900	25.272		

5	14.356	-12.187	18.831	0.151	-1.687
6	-37.156	1.287	37.178	0.367	-0.598
8	-30.000	0.826	30.011		
6	-29.425	3.196	29.598	0.103	-0.558
28	-0.575	-2.370	2.438	0.000	-4.368
10	-5.800	17.000	17.962		
6	-15.823	0.626	15.835	0.000	1.278
9	-27.693	-5.932	28.321	0.000	0.809
20	9.027	3.560	9.704	0.081	0.180
17	5.372	4.414	6.953	0.014	0.037
21	15.733	9.842	18.558	0.110	0.237
22	7.583	4.490	8.813	0.052	0.107
11	0.000	16.119	16.119		
9	-0.000	16.119	16.119	0.000	0.462
12	-11.200	-7.500	13.479		
4	-44.121	-9.961	45.232	0.000	4.685
13	0.000	-10.291	10.291	0.000	0.133
14	7.856	2.442	8.227	0.075	0.155
15	17.857	6.947	19.161	0.217	0.428
16	7.208	3.363	7.954	0.053	0.112

13 0.000 10.423 10.423

12 -0.000 10.424 10.424 0.000 0.133

14 -6.200 -1.600 6.403

12 -7.782 -2.287 8.111 0.075 0.155

15 1.582 0.687 1.724 0.006 0.005

15 -8.200 -2.500 8.573

12 -17.640 -6.519 18.806 0.217 0.428

14 -1.576 -0.681 1.717 0.006 0.005

18 6.014 1.744 6.262 0.039 0.080

23 5.001 2.956 5.810 0.031 0.063

16 -3.500 -1.800 3.936

12 -7.154 -3.251 7.858 0.053 0.112

17 3.654 1.451 3.932 0.012 0.027

17 -9.000 -5.800 10.707

16 -3.643 -1.424 3.911 0.012 0.027

10 -5.357 -4.376 6.918 0.014

18 -3.200 -0.900 3.324

15 -5.975 -1.665 6.203 0.039 0.080

19 2.775 0.765 2.879 0.005 0.010

19		-9.500	-3.400	10.090	
18	-2.770	-0.755	2.871	0.005	0.010
20	-6.730	-2.645	7.231	0.017	0.034
20		-2.200	-0.700	2.309	
19	6.747	2.679	7.259	0.017	0.034
10	-8.947	-3.379	9.564	0.081	0.180
21		-17.500	-11.200	20.777	
10	-15.623	-9.606	18.340	0.110	0.237
22	-1.877	-1.594	2.462	0.001	0.001
22		0.000	0.000	0.000	
10	-7.531	-4.384	8.714	0.052	0.107
21	1.877	1.596	2.464	0.001	0.001
24	5.654	2.788	6.304	0.043	0.067
23		-3.200	-1.600	3.578	
15	-4.970	-2.893	5.751	0.031	0.063
24	1.770	1.293	2.192	0.006	0.012
24		-8.700	-2.400	9.025	
22	-5.611	-2.721	6.236	0.043	0.067
23	-1.764	-1.280	2.180	0.006	0.012
25	-1.325	1.602	2.079	0.008	0.014
25		0.000	0.000	0.000	

	24	1.333	-1.588	2.073	0.008	0.014	
	26	3.545	2.366	4.262	0.045	0.066	
	27	-4.877	-0.778	4.939	0.026	0.049	
26		-3.500	-2.300	4.188			
	25	-3.500	-2.300	4.188	0.045	0.066	
27		0.000	0.000	0.000			
	25	4.903	0.827	4.972	0.026	0.049	
	28	-18.184	-4.157	18.653	0.000	1.309	
	29	6.189	1.668	6.410	0.086	0.162	
	30	7.091	1.661	7.283	0.161	0.30	
28		0.000	0.000	0.000			
	27	18.184	5.466	18.987	0.000	1.309	0.968
	8	0.575	-1.999	2.080	0.000	-4.368	
	6	-18.759	-3.467	19.077	0.060	-13.086	
29		-2.400	-0.900	2.563			
	27	-6.104	-1.506	6.286	0.086	0.162	
	30	3.704	0.606	3.753	0.033	0.063	
30		-10.600	-1.900	10.769			
	27	-6.930	-1.358	7.062	0.161	0.304	
	29	-3.670	-0.542	3.710	0.033	0.063	
Total loss					17.599	22.244	

The matlab programs for examples of chapter 4:

Example 4.1:

```
%ifgauss
Vm=0;
delta=0;
yload=0;
deltad =0;
nbus = length(busdata(:,1));
kb=[];
Vm=[];
delta=[];
Pd=[];
Qd=[];
Pg=[];
Qg=[];
Qmin=[];
Qmax=[];
Pk=[];
P=[];
Qk=[];
Q=[];
S=[];
V=[];
for k=1:nbus
n=busdata(k,1);
kb(n)=busdata(k,2);
Vm(n)=busdata(k,3);
delta(n)=busdata(k, 4);
Pd(n)=busdata(k,5);
Qd(n)=busdata(k,6);
```

```
Pg(n)=busdata(k,7);
Qg(n) = busdata(k,8);
Qmin(n)=busdata(k, 9);
Qmax(n)=busdata(k, 10);
Qsh(n)=busdata(k, 11);
if Vm(n) <= 0  Vm(n) = 1.0;
V(n) = 1 + j*0;
else delta(n) = pi/180*delta(n);
V(n) = Vm(n)*(cos(delta(n)) + j*sin(delta(n)));
P(n)=(Pg(n)-Pd(n))/basemva;
Q(n)=(Qg(n)-Qd(n)+ Qsh(n))/basemva;
S(n) = P(n) + j*Q(n);
end
DV(n)=0;
end
num = 0;
AcurBus = 0;
converge = 1;
Vc = zeros(nbus,1)+j*zeros(nbus,1);
Sc = zeros(nbus,1)+j*zeros(nbus,1);
while exist('accel')~=1
accel = 1.3;
end
while exist('accuracy')~=1
accuracy = 0.001;
end
while exist('basemva')~=1
basemva= 100;
end
while exist('maxiter')~=1
maxiter = 100;
end
```

```
mline=ones(nbr,1);
for k=1:nbr
for m=k+1:nbr
if((nl(k)==nl(m)) & (nr(k)==nr(m)));
mline(m)=2;
elseif ((nl(k)==nr(m)) & (nr(k)==nl(m)));
mline(m)=2;
else, end
end
end
iter=0;
maxerror=10;
while maxerror >= accuracy &
iter <= maxiter
iter=iter+1;
for n = 1:nbus;
YV = 0+j*0;
for L = 1:nbr;
if (nl(L) == n &
mline(L) == 1), k=nr(L);
%modified to handle parallel lines (
YV = YV + Ybus(n,k)*V(k);
elseif (nr(L) == n & mline(L)==1),
 k=nl(L); %modified to handle parallel lines
```

```
YV = YV + Ybus(n,k)*V(k);
end end
Sc = conj(V(n))*(Ybus(n,n)*V(n) + YV) ;
Sc = conj(Sc);
DP(n) = P(n) - real(Sc);
DQ(n) = Q(n) - imag(Sc);
if kb(n) == 1
S(n) =Sc; P(n) = real(Sc); Q(n) = imag(Sc); DP(n)
=0; DQ(n)=0;
Vc(n) = V(n);
elseif kb(n) == 2
Q(n) = imag(Sc); S(n) = P(n) + j*Q(n);
if Qmax(n) ~= 0
Qgc = Q(n)*basemva + Qd(n) - Qsh(n);
if abs(DQ(n)) <= .005 & iter >= 10 % After 10
iterations
if DV(n) <= 0.045   % the Mvar of generator buses
are
if Qgc < Qmin(n), % tested. If not within limits
Vm(n)
Vm(n) = Vm(n) + 0.005;% is changed in steps of
0.005 pu
DV(n) = DV(n)+.005; % up to .05  pu in order to
bring
elseif Qgc > Qmax(n) % the generator Mvar within
the
Vm(n) = Vm(n) - 0.005;  % specified limits.
DV(n)=DV(n)+.005; end
else, end
else,end
else,end
end
```

```
if kb(n) ~= 1
Vc(n)    =    (conj(S(n))/conj(V(n))    -    YV    )/
Ybus(n,n);
else, end
if kb(n) == 0
V(n) = V(n) + accel*(Vc(n)-V(n));
elseif kb(n) == 2
VcI = imag(Vc(n));
VcR = sqrt(Vm(n)^2 - VcI^2);
Vc(n) = VcR + j*VcI;
V(n) = V(n) + accel*(Vc(n) -V(n));
End end
maxerror=max(max(abs(real(DP))),
max(abs(imag(DQ))) )
if iter == maxiter & maxerror > accuracy
fprintf('\nWARNING:  Iterative  solution  did  not
converged after ')
fprintf('%g', iter), fprintf(' iterations.\n\n')
fprintf('Press Enter to terminate the iterations
and print the results \n')
converge = 0; pause, else, end, end
if converge ~= 1
tech= ('  ITERATIVE SOLUTION DID NOT CONVERGE');
else,
tech=('Power   Flow   Solution   by   Gauss-Seidel
Method');
end
k=0;
for n = 1:nbus
Vm(n) = abs(V(n));
deltad(n) = angle(V(n))*180/pi;
if kb(n) == 1
S(n)=P(n)+j*Q(n);
```

```
Pg(n) = P(n)*basemva + Pd(n);
Qg(n) = Q(n)*basemva + Qd(n) - Qsh(n);
k=k+1;
Pgg(k)=Pg(n);
elseif  kb(n) ==2
k=k+1;
Pgg(k)=Pg(n);
S(n)=P(n)+j*Q(n);
Qg(n) = Q(n)*basemva + Qd(n) - Qsh(n);
end
yload(n)                    =                    (Pd(n)-
j*Qd(n)+j*Qsh(n))/(basemva*Vm(n)^2);
end
Pgt = sum(Pg);  Qgt = sum(Qg); Pdt = sum(Pd); Qdt
= sum(Qd); Qsht = sum(Qsh);
busdata(:,3)=Vm'; busdata(:,4)=deltad';
clear  AcurBus  DP  DQ  DV  L Sc Vc VcI VcR YV
converge delta
```

for Ifybus:

```
%ifybus
j=sqrt(-1); i = sqrt(-1);
nl = linedata(:,1); nr = linedata(:,2);
R = linedata(:,3);
X      =      linedata(:,4);      Bc      =
j*linedata(:,5); a = linedata(:, 6);
nbr=length(linedata(:,1));     nbus     =
max(max(nl), max(nr));
Z  =  R  +  j*X;  y= ones(nbr,1)./Z;%branch
admittance
for n = 1:nbr
```

```
if a(n) <= 0  a(n) = 1; else end
Ybus=zeros(nbus,nbus);   % initialize Ybus to zero
% formation of the off diagonal elements
for k=1:nbr;
Ybus(nl(k),nr(k))=Ybus(nl(k),nr(k))-y(k)/a(k);
Ybus(nr(k),nl(k))=Ybus(nl(k),nr(k));
end
end
% formation of the diagonal elements
for  n=1:nbus
for k=1:nbr
if nl(k)==n
Ybus(n,n) = Ybus(n,n)+y(k)/(a(k)^2) + Bc(k);
elseif nr(k)==n
Ybus(n,n) = Ybus(n,n)+y(k) +Bc(k);
else, end
end
end
clear Pgg
```

for bus out :

```
%busout  Example 4.1
disp(tech)
fprintf(  Maximum  Power  Mismatch  =  %g  \n',
maxerror)
fprintf('               No. of Iterations = %g
            \n\n', iter)
head =['    Bus  Voltage  Angle
            -------Load------       ---Generation---
           Injected'
```

```
'        No.   Mag.        Degree        MW            Mvar
MW        Mvar        Mvar '
           '
           '];
disp(head)
for n=1:nbus
fprintf(' %3g', n), fprintf(' %7.3f', Vm(n)),
fprintf('  %8.3f',  deltad(n)),  fprintf('  %9.3f',
Pd(n)),
fprintf('   %9.3f',   Qd(n)),     fprintf('   %9.3f',
Pg(n)),
fprintf('  %9.3f  ',  Qg(n)),  fprintf('  %8.3f\n',
Qsh(n))
end
fprintf('    \n'),fprintf('    Total              ')
fprintf(' %9.3f', Pdt), fprintf(' %9.3f', Qdt),
fprintf('  %9.3f',  Pgt),  fprintf('  %9.3f',  Qgt),
fprintf(' %9.3f\n\n', Qsht)
```

for lineflow:

```
% lineflow
SLT = 0;
fprintf('\n')
fprintf('            Line Flow and Losses \n\n')
fprintf('      --Line--   Power at bus & line flow
           --Line loss--  Transformer\n')
fprintf('  from  to     MW    Mvar    MVA
           MW     Mvar       tap\n')
```

```
for n = 1:nbus
busprt = 0;
for L = 1:nbr;
if busprt == 0
fprintf('\n'),fprintf('%6g',n),fprintf('%9.3f',
P(n)*basemva)
fprintf('%9.3f',Q(n)*basemva),fprintf('%9.3f\n',
abs(S(n)*basemva))
busprt = 1;
else, end
if nl(L)==n      k = nr(L);
In =(V(n)-a(L)*V(k))*y(L)/a(L)^2 + Bc(L)/a(L)^2*V(n);
Ik = (V(k) - V(n)/a(L))*y(L) + Bc(L)*V(k);
Snk = V(n)*conj(In)*basemva;
Skn = V(k)*conj(Ik)*basemva;
SL  = Snk + Skn;
SLT = SLT + SL;
elseif nr(L)==n  k = nl(L);
In = (V(n) - V(k)/a(L))*y(L) + Bc(L)*V(n);
Ik =(V(k)- a(L)*V(n))*y(L)/a(L)^2+ Bc(L)/a(L)^2*V(k);
Snk = V(n)*conj(In)*basemva;
Skn = V(k)*conj(Ik)*basemva;
SL  = Snk + Skn;
SLT = SLT + SL;
else, end
if nl(L)==n | nr(L)==n
fprintf('%12g', k),
fprintf('%9.3f', real(Snk)), fprintf('%9.3f',
imag(Snk))
```

```
fprintf('%9.3f', abs(Snk)),
fprintf('%9.3f', real(SL)),
if nl(L) ==n & a(L) ~= 1
fprintf('%9.3f',   imag(SL)),   fprintf('%9.3f\n',
a(L))
else, fprintf('%9.3f\n', imag(SL))
end
else, end
end
end
SLT = SLT/2;
fprintf('   \n'), fprintf('    Total loss      ')
fprintf('%9.3f',real(SLT))      fprintf('%9.3f\n',
imag(SLT))
clear Ik In SL SLT Skn Snk
```

Example 4.2:

for this example all the above programs are same just in please of Ifgauss the program for Ifnewton can come , which is as follow:

```
%ifnewton 4.2
ns=0;  ng=0;  Vm=0;  delta=0;  yload=0;
deltad=0;
nbus = length(busdata(:,1));
kb=[];Vm=[];  delta=[];  Pd=[];  Qd=[];
Pg=[]; Qg=[]; Qmin=[]; Qmax=[];
Pk=[]; P=[]; Qk=[]; Q=[]; S=[]; V=[];
for k=1:nbus
n=busdata(k,1);
kb(n)=busdata(k,2);
```

```
Vm(n)=busdata(k,3); delta(n)=busdata(k, 4);
Pd(n)=busdata(k,5);            Qd(n)=busdata(k,6);
Pg(n)=busdata(k,7); Qg(n) = busdata(k,8);
Qmin(n)=busdata(k, 9); Qmax(n)=busdata(k, 10);
Qsh(n)=busdata(k, 11);
if Vm(n) <= 0  Vm(n) = 1.0; V(n) = 1 + j*0;
else delta(n) = pi/180*delta(n);
V(n) = Vm(n)*(cos(delta(n)) + j*sin(delta(n)));
P(n)=(Pg(n)-Pd(n))/basemva;
Q(n)=(Qg(n)-Qd(n)+ Qsh(n))/basemva;
S(n) = P(n) + j*Q(n);

end end
for k=1:nbus
if kb(k) == 1, ns = ns+1; else, end
if kb(k) == 2 ng = ng+1; else, end
ngs(k) = ng;
nss(k) = ns;
end
Ym=abs(Ybus); t = angle(Ybus);
m=2*nbus-ng-2*ns;
maxerror = 1; converge=1;
iter = 0;
% added for parallel lines
mline=ones(nbr,1);
for k=1:nbr
for m=k+1:nbr
if((nl(k)==nl(m)) & (nr(k)==nr(m)));
```

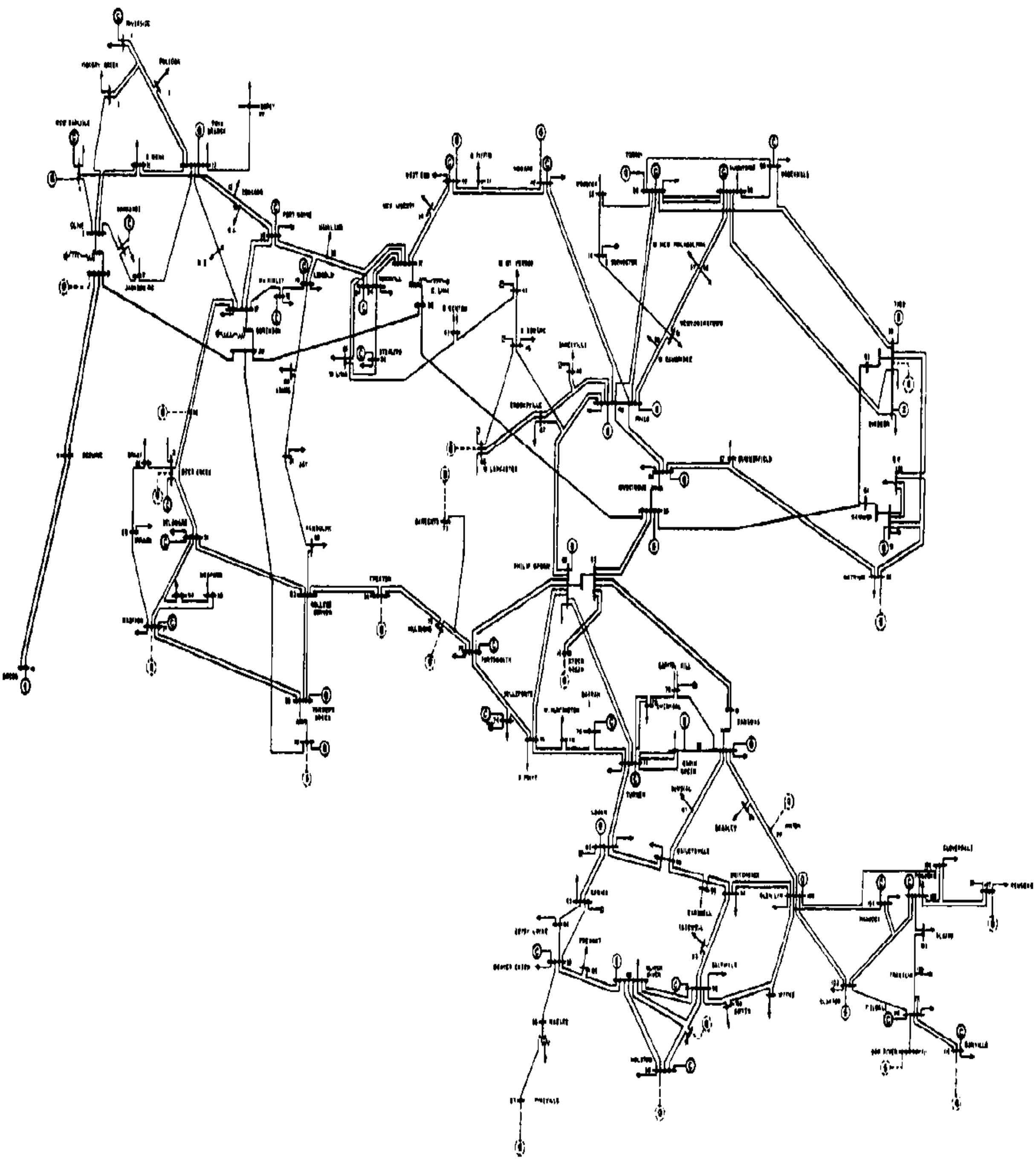
```
   delta(n) + delta(l));
J44=J44+    Vm(l)*Ym(n,l)*sin(t(n,l)-delta(n)    +
delta(l));
else, end
if kb(n) ~= 1  & kb(l) ~=1
lk = nbus+l-ngs(l)-nss(l)-ns;ll = l -nss(l);
% off diagonalelements of J1
A(nn,ll)          =-Vm(n)*Vm(l)*Ym(n,l)*sin(t(n,l)-
delta(n)+ delta(l));
if kb(l) == 0  % off diagonal elements of J2
A(nn,  lk)  =Vm(n)*Ym(n,l)*cos(t(n,l)-  delta(n)  +
delta(l));end
if kb(n) == 0  % off diagonal elements of J3
A(lm,    ll)     =-Vm(n)*Vm(l)*Ym(n,l)*cos(t(n,l)-
delta(n)+delta(l)); end
if  kb(n)  ==  0  &  kb(l)  ==  0   %  off  diagonal
elements of  J4
A(lm,  lk)  =-Vm(n)*Ym(n,l)*sin(t(n,l)-  delta(n)  +
delta(l));end
else end
else , end
else, end
end
Pk = Vm(n)^2*Ym(n,n)*cos(t(n,n))+J33;
2*Vm(n)*Ym(n,n)*sin(t(n,n))-J44;
%diagonal of elements of J4
```

```
Qk =-Vm(n)^2*Ym(n,n)*sin(t(n,n))-J11;
if kb(n) == 1 P(n)=Pk; Q(n) = Qk; end
% Swing bus P
if kb(n) == 2  Q(n)=Qk;
if Qmax(n) ~= 0
Qgc = Q(n)*basemva + Qd(n) - Qsh(n);
if iter <= 7                       % Between the 2th
& 6th iterations
if iter > 2                          % the Mvar of
generator buses are
if Qgc  < Qmin(n),         % tested. If not within
limits Vm(n)
Vm(n) = Vm(n) + 0.01;       % is changed in steps
of 0.01 pu to
elseif Qgc   > Qmax(n), % bring the generator
Mvar within
Vm(n) = Vm(n) -0.01;end % the specified limits.

else, end,else,end

else,end

end
if kb(n) ~= 1
A(nn,nn) = J11;%diagonal elements of J1
DC(nn) = P(n)-Pk;
end
if kb(n) == 0
A(nn,lm)    =    2*Vm(n)*Ym(n,n)*cos(t(n,n))+J22;
%diagonal elements of J2
A(lm,nn)= J33%diagonal elements of J3
A(lm,lm) =- DC(lm) = Q(n)-Qk;
end,end
```

```
DC(lm) = Q(n)-Qk;
end
end
DX=A\DC';
k=0;
for n = 1:nbus
if kb(n) == 1
k=k+1;
S(n)= P(n)+j*Q(n);
Pg(n) = P(n)*basemva + Pd(n);
Qg(n) = Q(n)*basemva + Qd(n) - Qsh(n);
Pgg(k)=Pg(n);
Qgg(k)=Qg(n);
elseif  kb(n) ==2
k=k+1;
S(n)=P(n)+j*Q(n);
Qg(n) = Q(n)*basemva + Qd(n) - Qsh(n);
Pgg(k)=Pg(n);
Qgg(k)=Qg(n);
end
yload(n)                                        (Pd(n)-
j*Qd(n)+j*Qsh(n))/(basemva*Vm(n)^2);
end
busdata(:,3)=Vm'; busdata(:,4)=deltad';
Pgt = sum(Pg);  Qgt = sum(Qg); Pdt = sum(Pd); Qdt =
sum(Qd); Qsht = sum(Qsh);

%clear A DC DX  J11 J22 J33 J44 Qk delta lk ll lm
%clear A DC DX  J11 J22 J33  Qk delta lk ll lm
```

CHAPTER 5

The data preparation for 118 bus system



Figure(5.1)

Data for 118 bus system as follow :

basemva = 100 ; accuracy = 0.001, accel = 1.8 , maxiter = 100;

% Bus Bus Vm Va PD QD PG QG Qmin Qmax Injected

% no. type MVAR

busdata= [

1	2	0.955	10.67	51	27	0.0	0.0	-5	15	0.0
2	0	0.971	11.22	20	9	0.0	0.0	0	0	0.0
3	0	0.968	11.56	39	10	0.0	0.0	0	0	0.0
4	2	0.998	15.28	39	12	-9.0	0.0	-300	300	0.0
5	0	1.002	15.73	0	0	0.0	0.0	0	0	0.0
6	2	0.99	13	52	22	0.0	0.0	-13	50	0.0
7	0	0.989	12.56	19	2	0.0	0.0	0	0	0.0
8	2	1.015	20.77	28	0	-28.0	0.0	-300	300	0.0
9	0	1.043	28.02	0	0	0.0	0.0	0	0	0.0
10	2	1.05	35.61	0	0	450.0	0.0	-147	200	0.0
11	0	0.985	12.72	70	23	0.0	0.0	0	0	0.0
12	2	0.99	12.2	47	10	85.0	0.0	-35	120	0.0
13	0	0.968	11.35	34	16	0.0	0.0	0	0	0.0
14	0	0.984	11.5	14	1	0.0	0.0	0	0	0.0
15	2	0.97	11.23	90	30	0.0	0.0	-10	30	0.0
16	0	0.984	11.91	25	10	0.0	0.0	0	0	0.0
17	0	0.995	13.74	11	3	0.0	0.0	0	0	0.0
18	2	0.973	11.53	60	34	0.0	0.0	-16	50	0.0

19	2	0.963	11.05	45	25	0.0	0.0	-8	24	0.0
20	0	0.958	11.93	18	3	0.0	0.0	0	0	0.0
21	0	0.959	13.52	14	8	0.0	0.0	0	0	0.0
22	0	0.97	16.08	10	5	0.0	0.0	0	0	0.0
23	0	1	21	7	3	0.0	0.0	0	0	0.0
24	2	0.992	20.89	13	0	-13.0	0.0	-300	300	0.0
25	2	1.05	27.93	0	0	220.0	0.0	-47	140	0.0
26	2	1.015	29.71	0	0	314.0	0.0	-1000	1000	0.0
27	2	0.968	15.35	71	13	-9.0	0.0	-300	300	0.0
28	0	0.962	13.62	17	7	0.0	0.0	0	0	0.0
29	0	0.963	12.63	24	4	0.0	0.0	0	0	0.0
30	0	0.968	18.79	0	0	0.0	0.0	0	0	0.0
31	2	0.967	12.75	43	27	7.0	0.0	-300	300	0.0
32	2	0.964	14.8	59	23	0.0	0.0	-14	42	0.0
33	0	0.972	10.63	23	9	0.0	0.0	0	0	0.0
34	2	0.986	11.3	59	26	0.0	0.0	-8	24	0.0
35	0	0.981	10.87	33	9	0.0	0.0	0	0	0.0
36	2	0.98	10.87	31	17	0.0	0.0	-8	24	0.0
37	0	0.992	11.77	0	0	0.0	0.0	0	0	0.0
38	0	0.962	16.91	0	0	0.0	0.0	0	0	0.0
39	0	0.97	8.41	27	11	0.0	0.0	0	0	0.0

40	2	0.97	7.35	66	23	-46.0	0.0	-300	300	0.0
41	0	0.967	6.92	37	10	0.0	0.0	0	0	0.0
42	2	0.985	8.53	96	23	-59.0	0.0	-300	300	0.0
43	0	0.978	11.28	18	7	0.0	0.0	0	0	0.0
44	0	0.985	13.82	16	8	19.0	0.0	0	0	0.0
45	0	0.987	15.67	53	22	0.0	0.0	0	0	0.0
46	2	1.005	18.49	28	10	0.0	0.0	-100	100	0.0
47	0	1.017	20.73	34	0	0.0	0.0	0	0	0.0
48	0	1.021	19.93	20	11	0.0	0.0	0	0	0.0
49	2	1.025	20.94	87	30	204.0	0.0	-85	210	0.0
50	0	1.001	18.9	17	4	0.0	0.0	0	0	0.0
51	0	0.967	16.28	17	8	0.0	0.0	0	0	0.0
52	0	0.957	15.32	18	5	0.0	0.0	0	0	0.0
53	0	0.946	14.35	23	11	0.0	0.0	0	0	0.0
54	2	0.955	15.26	113	32	48.0	0.0	-300	300	0.0
55	2	0.952	14.97	63	22	0.0	0.0	-8	23	0.0
56	2	0.954	15.16	84	18	0.0	0.0	-8	15	0.0
57	0	0.971	16.36	12	3	0.0	0.0	0	0	0.0
58	0	0.959	15.51	12	3	0.0	0.0	0	0	0.0
59	2	0.985	19.37	277	113	155.0	0.0	-60	180	0.0
60	0	0.993	23.15	78	3	0.0	0.0	0	0	0.0
61	2	0.995	24.04	0	0	160.0	0.0	-100	300	0.0
62	2	0.998	23.43	77	14	0.0	0.0	-20	20	0.0

63	0	0.969	22.75	0	0	0.0	0.0	0	0	0.0
64	0	0.984	24.52	0	0	0.0	0.0	0	0	0.0
65	2	1.005	27.65	0	0	391.0	0.0	-67	200	0.0
66	2	1.05	27.48	39	18	392.0	0.0	-67	200	0.0
67	0	1.02	24.84	28	7	0.0	0.0	0	0	0.0
68	0	1.003	27.55	0	0	0.0	0.0	0	0	0.0
69	1	1.035	30	0	0	516.4	0.0	-300	300	0.0
70	2	0.984	22.58	66	20	0.0	0.0	-10	32	0.0
71	0	0.987	22.15	0	0	0.0	0.0	0	0	0.0
72	2	0.98	20.98	12	0	-12.0	0.0	-100	100	0.0
73	2	0.991	21.94	6	0	-6.0	0.0	-100	100	0.0
74	2	0.958	21.64	68	27	0.0	0.0	-6	9	0.0
75	0	0.967	22.91	47	11	0.0	0.0	0	0	0.0
76	2	0.943	21.77	68	36	0.0	0.0	-8	23	0.0
77	2	1.006	26.72	61	28	0.0	0.0	-20	70	0.0
78	0	1.003	26.42	71	26	0.0	0.0	0	0	0.0
79	0	1.009	26.72	39	32	0.0	0.0	0	0	0.0
80	2	1.04	28.96	130	26	477.0	0.0	-165	280	0.0
81	0	0.997	28.1	0	0	0.0	0.0	0	0	0.0
82	0	0.989	27.24	54	27	0.0	0.0	0	0	0.0
83	0	0.985	28.42	20	10	0.0	0.0	0	0	0.0

84	0	0.98	30.95	11	7	0.0	0.0	0	0	0.0
85	2	0.985	32.51	24	15	0.0	0.0	-8	23	0.0
86	0	0.987	31.14	21	10	0.0	0.0	0	0	0.0
87	2	1.015	31.4	0	0	4.0	0.0	-100	1000	0.0
88	0	0.987	35.64	48	10	0.0	0.0	0	0	0.0
89	2	1.005	39.69	0	0	607.0	0.0	-210	300	0.0
90	2	0.985	33.29	163	42	-85.0	0.0	-300	300	0.0
91	2	0.98	33.31	10	0	-10.0	0.0	-100	100	0.0
92	2	0.993	33.8	65	10	0.0	0.0	-3	9	0.0
93	0	0.987	30.79	12	7	0.0	0.0	0	0	0.0
94	0	0.991	28.64	30	16	0.0	0.0	0	0	0.0
95	0	0.981	27.67	42	31	0.0	0.0	0	0	0.0
96	0	0.993	27.51	38	15	0.0	0.0	0	0	0.0
97	0	1.011	27.88	15	9	0.0	0.0	0	0	0.0
98	0	1.024	27.4	34	8	0.0	0.0	0	0	0.0
99	2	1.01	27.04	42	0	-42.0	0.0	-100	100	0.0
100	2	1.017	28.03	37	18	250.0	0.0	-50	155	0.0
101	0	0.993	29.61	22	15	0.0	0.0	0	0	0.0
102	0	0.991	32.3	5	3	0.0	0.0	0	0	0.0
103	2	1.001	24.44	23	16	40.0	0.0	-15	40	0.0
104	2	0.971	21.69	38	25	0.0	0.0	-8	23	0.0

105	2	0.965	20.57	31	26	0.0	0.0	-8	23	0.0
106	0	0.962	20.32	43	16	0.0	0.0	0	0	0.0
107	2	0.952	17.53	50	12	-22.0	0.0	-200	200	0.0
108	0	0.967	19.38	2	1	0.0	0.0	0	0	0.0
109	0	0.967	18.93	8	3	0.0	0.0	0	0	0.0
110	2	0.973	18.09	39	30	0.0	0.0	-8	23	0.0
111	2	0.98	19.74	0	0	36.0	0.0	-100	1000	0.0
112	2	0.975	14.99	68	13	-43.0	0.0	-100	1000	0.0
113	2	0.993	13.74	6	0	-6.0	0.0	-100	200	0.0
114	0	0.96	14.46	8	3	0.0	0.0	0	0	0.0
115	0	0.96	14.46	22	7	0.0	0.0	0	0	0.0
116	2	1.005	27.12	184	0	-184.0	0.0	-1000	1000	0.0
117	0	0.974	10.67	20	8	0.0	0.0	0	0	0.0
118	0	0.949	21.92	33	15	0.0	0.0	0	0	0.0];

The line data is as flow :

```
%From  To   R   X    B/2    Transformer
%Bus   Bus  PU  PU          Tap Setting

linedata = [
    1   2   0.0303   0.0999   0.0127    0   0.0254
    1   3   0.0129   0.0424   0.00541   0   0.01082
```

4	5	0.00176	0.00798	0.00105	0	0.0021
3	5	0.0241	0.108	0.0142	0	0.0284
5	6	0.0119	0.054	0.00713	0	0.01426
6	7	0.00459	0.0208	0.00275	0	0.0055
8	9	0.00244	0.0305	0.581	0	1.162
8	50	0.0267	0	0.985	0	
9	10	0.00258	0.0322	0.615	0	1.23
4	11	0.0209	0.0688	0.00874	0	0.01748
5	11	0.0203	0.0682	0.00869	0	0.01738
11	12	0.00595	0.0196	0.00251	0	0.00502
2	12	0.0187	0.0616	0.00786	0	0.01572
3	12	0.0484	0.16	0.0203	0	0.0406
7	12	0.00862	0.034	0.00437	0	0.00874
11	13	0.02225	0.0731	0.00938	0	0.01876
12	14	0.0215	0.0707	0.00908	0	0.01816
13	15	0.0744	0.2444	0.03134	0	0.06268
14	15	0.0595	0.195	0.0251	0	0.0502
12	16	0.0212	0.0834	0.0107	0	0.0214
15	17	0.0132	0.0437	0.0222	0	0.0444
16	17	0.0454	0.1801	0.0233	0	0.0466
17	18	0.0123	0.0505	0.00649	0	0.01298

18	19	0.01119	0.0493	0.00571	0	0.01142
19	20	0.0252	0.117	0.0149	0	0.0298
15	19	0.012	0.0394	0.00505	0	0.0101
20	21	0.0183	0.0849	0.0108	0	0.0216
21	22	0.0209	0.097	0.0123	0	0.0246
22	23	0.0342	0.159	0.0202	0	0.0404
23	24	0.0135	0.0492	0.0249	0	0.0498
23	25	0.0156	0.08	0.0432	0	0.0864
26	25	0	0.0382	0	0.96	0
25	27	0.0318	0.163	0.0882	0	0.1764
27	28	0.01913	0.0855	0.0108	0	0.0216
28	29	0.0237	0.0943	0.0119	0	0.0238
30	17	0	0.0388	0	0.96	0
8	30	0.00431	0.0504	0.257	0	0.514
26	30	0.00799	0.086	0.454	0	0.908
17	31	0.0474	0.1563	0.01995	0	0.0399
29	31	0.0108	0.0331	0.00415	0	0.0083
23	32	0.0317	0.1153	0.05865	0	0.1173
31	32	0.0298	0.0985	0.01255	0	0.0251
27	32	0.0229	0.0755	0.00963	0	0.01926
15	33	0.038	0.1244	0.01597	0	0.03194
19	34	0.0752	0.247	0.0316	0	0.0632

35	36	0.00224	0.0102	0.00134	0	0.00268
35	37	0.011	0.0497	0.00659	0	0.01318
33	37	0.0415	0.142	0.0183	0	0.0366
34	36	0.00871	0.0268	0.00284	0	0.00568
34	37	0.00256	0.0094	0.00492	0	0.00984
38	37	0	0.0375	0	0.935	0
37	39	0.0321	0.106	0.0135	0	0.027
37	40	0.0593	0.168	0.021	0	0.042
30	38	0.00464	0.054	0.211	0	0.422
39	40	0.0184	0.0605	0.00776	0	0.01552
40	41	0.0145	0.0487	0.00611	0	0.01222
40	42	0.0555	0.183	0.0233	0	0.0466
41	42	0.041	0.135	0.0172	0	0.0344
43	44	0.0608	0.2454	0.03034	0	0.06068
34	43	0.0413	0.1681	0.02113	0	0.04226
44	45	0.0224	0.0901	0.0112	0	0.0224
45	46	0.04	0.1356	0.0166	0	0.0332
46	47	0.038	0.127	0.0158	0	0.0316
46	48	0.0601	0.189	0.0236	0	0.0472
47	49	0.0191	0.0625	0.00802	0	0.01604
42	49	0.0715	0.323	0.043	0	0.086

42	49	0.0715	0.323	0.043	0	0.086
45	*49*	*0.0684*	*0.186*	*0.0222*	*0*	*0.0444*
48	*49*	*0.0179*	*0.0505*	*0.00629*	*0*	*0.01258*
49	*50*	*0.0267*	*0.0752*	*0.00937*	*0*	*0.01874*
49	*51*	*0.0486*	*0.137*	*0.0171*	*0*	*0.0342*
51	*52*	*0.0203*	*0.0588*	*0.00698*	*0*	*0.01396*
52	*53*	*0.0405*	*0.1635*	*0.02029*	*0*	*0.04058*
53	*54*	*0.0263*	*0.122*	*0.0155*	*0*	*0.031*
49	*54*	*0.073*	*0.289*	*0.0369*	*0*	*0.0738*
49	*54*	*0.0869*	*0.291*	*0.0365*	*0*	*0.073*
54	*55*	*0.0169*	*0.0707*	*0.0101*	*0*	*0.0202*
54	*56*	*0.00275*	*0.00955*	*0.00366*	*0*	*0.00732*
55	*56*	*0.00488*	*0.0151*	*0.00187*	*0*	*0.00374*
56	*57*	*0.0343*	*0.0966*	*0.0121*	*0*	*0.0242*
50	*57*	*0.0474*	*0.134*	*0.0166*	*0*	*0.0332*
56	*58*	*0.0343*	*0.0966*	*0.0121*	*0*	*0.0242*
51	*58*	*0.0255*	*0.0719*	*0.00894*	*0*	*0.01788*
54	*59*	*0.0503*	*0.2293*	*0.0299*	*0*	*0.0598*
56	*59*	*0.0825*	*0.251*	*0.02845*	*0*	*0.0569*
56	*59*	*0.0803*	*0.239*	*0.0268*	*0*	*0.0536*
55	*59*	*0.04739*	*0.2158*	*0.02823*	*0*	*0.05646*

59	*60*	*0.0317*	*0.145*	*0.0188*	*0*	*0.0376*
59	*61*	*0.0328*	*0.15*	*0.0194*	*0*	*0.0388*
60	*61*	*0.00264*	*0.0135*	*0.00728*	*0*	*0.01456*
60	*62*	*0.0123*	*0.0561*	*0.00734*	*0*	*0.01468*
61	*62*	*0.00824*	*0.0376*	*0.0049*	*0*	*0.0098*
63	*59*	*0*	*0.0386*	*0*	*0.96*	*0*
63	*64*	*0.00172*	*0.02*	*0.108*	*0*	*0.216*
64	*61*	*0*	*0.0268*	*0*	*0.985*	*0*
38	*65*	*0.00901*	*0.0986*	*0.523*	*0*	*1.046*
64	*65*	*0.00269*	*0.0302*	*0.19*	*0*	*0.38*
49	*66*	*0.018*	*0.0919*	*0.0124*	*0*	*0.0248*
49	*66*	*0.018*	*0.0919*	*0.0124*	*0*	*0.0248*
62	*66*	*0.0482*	*0.218*	*0.0289*	*0*	*0.0578*
62	*67*	*0.0258*	*0.117*	*0.0155*	*0*	*0.031*
65	*66*	*0*	*0.037*	*0*	*0.935*	*0*
66	*67*	*0.0224*	*0.1015*	*0.01341*	*0*	*0.02682*
65	*68*	*0.00138*	*0.016*	*0.319*	*0*	*0.638*
47	*69*	*0.0844*	*0.2778*	*0.03546*	*0*	*0.07092*
49	*69*	*0.0985*	*0.324*	*0.0414*	*0*	*0.0828*

68	*69*	*0*	*0.037*	*0*	*0.935*	*0*
69	*70*	*0.03*	*0.127*	*0.061*	*0*	*0.122*
24	*70*	*0.00221*	*0.4115*	*0.05099*	*0*	*0.10198*
70	*71*	*0.00882*	*0.0355*	*0.00439*	*0*	*0.00878*
24	*72*	*0.0488*	*0.196*	*0.0244*	*0*	*0.0488*
71	*72*	*0.0446*	*0.18*	*0.02222*	*0*	*0.04444*
71	*73*	*0.00866*	*0.0454*	*0.00589*	*0*	*0.01178*
70	*74*	*0.0401*	*0.1323*	*0.01684*	*0*	*0.03368*
70	*75*	*0.0428*	*0.141*	*0.018*	*0*	*0.036*
69	*75*	*0.0405*	*0.122*	*0.062*	*0*	*0.124*
74	*75*	*0.0123*	*0.0406*	*0.00517*	*0*	*0.01034*
76	*77*	*0.0444*	*0.148*	*0.0184*	*0*	*0.0368*
69	*77*	*0.0309*	*0.101*	*0.0519*	*0*	*0.1038*
75	*77*	*0.0601*	*0.1999*	*0.02489*	*0*	*0.04978*
77	*78*	*0.00376*	*0.0124*	*0.00632*	*0*	*0.01264*
78	*79*	*0.00546*	*0.0244*	*0.00324*	*0*	*0.0064*
77	*80*	*0.017*	*0.0485*	*0.0236*	*0*	*0.0472*
77	*80*	*0.0294*	*0.105*	*0.0114*	*0*	*0.0228*
79	*80*	*0.0156*	*0.0704*	*0.00935*	*0*	*0.0187*
68	*81*	*0.00175*	*0.0202*	*0.404*	*0*	*0.808*
81	*80*	*0*	*0.037*	*0*	*0.935*	*0*
77	*82*	*0.0298*	*0.0853*	*0.04087*	*0*	*0.08174*

82	83	0.0112	0.03665	0.01898	0	0.03796
83	84	0.0625	0.132	0.0129	0	0.0258
83	85	0.043	0.148	0.0174	0	0.0348
84	85	0.0302	0.0641	0.00617	0	0.01234
85	86	0.035	0.123	0.0138	0	0.0276
86	87	0.02828	0.2074	0.02225	0	0.0445
85	88	0.02	0.102	0.0138	0	0.0276
85	89	0.0239	0.173	0.0235	0	0.047
88	89	0.0139	0.0712	0.00967	0	0.01934
89	90	0.0518	0.188	0.0264	0	0.0528
89	90	0.0238	0.0997	0.053	0	0.106
90	91	0.0254	0.0836	0.0107	0	0.0214
89	92	0.0099	0.0505	0.0274	0	0.0548
89	92	0.0393	0.1581	0.0207	0	0.0414
91	92	0.0387	0.1272	0.01634	0	0.03268
92	93	0.0258	0.0848	0.0109	0	0.0218
92	94	0.0481	0.158	0.0203	0	0.0406
93	94	0.0223	0.0732	0.00938	0	0.01876
94	95	0.0132	0.0434	0.00555	0	0.0111
80	96	0.0356	0.182	0.0247	0	0.0494
82	96	0.0162	0.053	0.0272	0	0.0544
94	96	0.0269	0.0869	0.0115	0	0.023
80	97	0.0183	0.0934	0.0127	0	0.0254

80	*98*	*0.0238*	*0.108*	*0.0143*	*0*	*0.0286*
80	*99*	*0.0454*	*0.206*	*0.0273*	*0*	*0.0546*
92	*100*	*0.0648*	*0.295*	*0.0236*	*0*	*0.0472*
94	*100*	*0.0178*	*0.058*	*0.0302*	*0*	*0.0604*
95	*96*	*0.0171*	*0.0547*	*0.00737*	*0*	*0.01474*
96	*97*	*0.0173*	*0.0885*	*0.012*	*0*	*0.024*
98	*100*	*0.0397*	*0.179*	*0.0238*	*0*	*0.0476*
99	*100*	*0.018*	*0.0813*	*0.0108*	*0*	*0.0216*
100	*101*	*0.0277*	*0.1262*	*0.0164*	*0*	*0.0328*
92	*102*	*0.0123*	*0.0559*	*0.00732*	*0*	*0.01464*
101	*102*	*0.0246*	*0.112*	*0.0147*	*0*	*0.0294*
100	*103*	*0.016*	*0.0525*	*0.0268*	*0*	*0.0536*
100	*104*	*0.0451*	*0.204*	*0.02705*	*0*	*0.0541*
103	*104*	*0.0466*	*0.1584*	*0.02035*	*0*	*0.0407*
103	*105*	*0.0535*	*0.1625*	*0.0204*	*0*	*0.0408*
100	*106*	*0.0605*	*0.229*	*0.031*	*0*	*0.062*
104	*105*	*0.00994*	*0.0378*	*0.00493*	*0*	*0.00986*
105	*106*	*0.014*	*0.0547*	*0.00717*	*0*	*0.01434*
105	*107*	*0.053*	*0.183*	*0.0236*	*0*	*0.0472*
105	*108*	*0.0261*	*0.0703*	*0.00922*	*0*	*0.01844*
106	*107*	*0.053*	*0.183*	*0.0236*	*0*	*0.0472*
108	*109*	*0.0105*	*0.0288*	*0.0038*	*0*	*0.0076*
103	*110*	*0.03906*	*0.1813*	*0.02305*	*0*	*0.0461*

109	*110*	*0.0278*	*0.0762*	*0.0101*	*0*	*0.0202*
110	*111*	*0.022*	*0.0755*	*0.01*	*0*	*0.02*
110	*112*	*0.0247*	*0.064*	*0.031*	*0*	*0.062*
17	*113*	*0.00913*	*0.0301*	*0.00384*	*0*	*0.00768*
32	*113*	*0.0615*	*0.203*	*0.0259*	*0*	*0.0518*
32	*114*	*0.0135*	*0.0612*	*0.00814*	*0*	*0.01628*
27	*115*	*0.0164*	*0.0741*	*0.00986*	*0*	*0.01972*
114	*115*	*0.0023*	*0.0104*	*0.00138*	*0*	*0.00276*
68	*116*	*0.00034*	*0.00405*	*0.082*	*0*	*0.164*
12	*117*	*0.0329*	*0.14*	*0.0179*	*0*	*0.0358*
75	*118*	*0.0145*	*0.0481*	*0.00599*	*0*	*0.01198*
76	*118*	*0.0164*	*0.0544*	*0.00678*	*0*	*0.01356*

The output is :

accuracy = 1.0000e-003

accel = 1.800

Power Flow Solution by Newton-Raphson Method

Maximum Power Mismatch = 8.05004e-007

No. of Iterations = 10

Bus Voltage Angle ------Load------ ---Generation--- Injected

No.	Mag.	Degree	MW	Mvar	MW	Mvar	Mvar
1	0.955	-1.230	51.000	27.000	0.000	-4.218	0.000
2	0.971	-0.656	20.000	9.000	0.000	0.000	0.000
3	0.968	-0.370	39.000	10.000	0.000	0.000	0.000
4	0.998	3.237	39.000	12.000	-9.000	-39.533	0.000
5	1.004	3.682	0.000	0.000	0.000	0.000	0.000
6	0.990	1.064	52.000	22.000	0.000	12.044	0.000
7	0.989	0.650	19.000	2.000	0.000	0.000	0.000
8	1.015	8.686	28.000	0.000	-28.000	56.180	0.000
9	1.043	15.940	0.000	0.000	0.000	0.000	0.000
10	1.050	23.521	0.000	0.000	450.000	-51.042	0.000
11	0.986	0.806	70.000	23.000	0.000	0.000	0.000
12	0.990	0.341	47.000	10.000	85.000	82.315	0.000
13	0.971	-0.469	34.000	16.000	0.000	0.000	0.000
14	0.986	-0.277	14.000	1.000	0.000	0.000	0.000
15	0.980	-0.300	90.000	30.000	0.000	30.434	0.000
16	0.985	0.200	25.000	10.000	0.000	0.000	0.000
17	0.997	2.348	11.000	3.000	0.000	0.000	0.000

18	0.973	0.201	60.000	34.000	0.000	2.475	0.000
19	0.973	-0.375	45.000	25.000	0.000	15.355	0.000
20	0.965	0.790	18.000	3.000	0.000	0.000	0.000
21	0.963	2.579	14.000	8.000	0.000	0.000	0.000
22	0.972	5.365	10.000	5.000	0.000	0.000	0.000
23	1.000	10.668	7.000	3.000	0.000	0.000	0.000
24	0.992	11.294	13.000	0.000	-13.000	-14.045	0.000
25	0.992	11.294	13.000	0.000	-13.000	-14.045	0.000
26	1.050	17.103	0.000	0.000	220.000	50.421	0.000
27	-1.015	18.746	0.000	0.000	314.000	10.274	0.000
28	0.968	4.136	71.000	13.000	-9.000	5.064	0.000
29	0.962	2.424	17.000	7.000	0.000	0.000	0.000
30	0.986	7.475	0.000	0.000	0.000	0.000	0.000
31	0.967	1.568	43.000	27.000	7.000	30.300	0.000
32	0.964	3.737	59.000	23.000	0.000	-11.169	0.000
33	0.978	-0.756	23.000	9.000	0.000	0.000	0.000
34	0.986	0.171	59.000	26.000	0.000	-56.994	0.000
35	0.989	-0.431	33.000	9.000	0.000	0.000	0.000
36	0.990	-0.440	31.000	17.000	0.000	47.054	0.000
37	0.995	0.515	0.000	0.000	0.000	0.000	0.000
38	0.960	6.388	0.000	0.000	0.000	0.000	0.000
39	0.970	-4.424	27.000	11.000	0.000	0.000	0.000
40	0.970	-6.418	66.000	23.000	-46.000	43.574	0.000
41	0.967	-6.840	37.000	10.000	0.000	0.000	*0.000*
42	0.985	-5.180	96.000	23.000	-59.000	72.834	*0.000*
43	0.971	1.827	18.000	7.000	0.000	0.000	0.000
44	0.971	6.894	16.000	8.000	19.000	0.000	0.000
45	0.976	8.525	53.000	22.000	0.000	0.000	0.000
46	1.005	10.891	28.000	10.000	0.000	25.122	0.000
47	1.013	14.274	34.000	0.000	0.000	0.000	0.000
48	1.014	12.668	20.000	11.000	0.000	0.000	0.000

49	1.025	13.612	87.000	30.000	204.000	173.422	0.000
50	1.001	11.609	17.000	4.000	0.000	0.000	0.000
51	0.967	9.035	17.000	8.000	0.000	0.000	0.000
52	0.957	8.094	18.000	5.000	0.000	0.000	0.000
53	0.946	7.151	23.000	11.000	0.000	0.000	0.000
54	0.955	8.087	113.000	32.000	48.000	3.731	0.000
55	0.952	7.808	63.000	22.000	0.000	4.663	0.000
56	0.954	7.988	84.000	18.000	0.000	-2.299	0.000
57	0.971	9.142	12.000	3.000	0.000	0.000	0.000
58	0.959	8.294	12.000	3.000	0.000	0.000	0.000
59	0.985	12.316	277.000	113.000	155.000	76.930	0.000
60	0.993	16.142	78.000	3.000	0.000	0.000	0.000
61	0.995	17.039	0.000	0.000	160.000	-40.366	0.000
62	0.998	16.408	77.000	14.000	0.000	1.208	0.000
63	0.969	15.747	0.000	0.000	0.000	0.000	0.000
64	0.984	17.541	0.000	0.000	0.000	0.000	0.000
65	1.005	20.742	0.000	0.000	391.000	99.828	0.000
66	1.050	20.406	39.000	18.000	392.000	-2.580	0.000
67	1.020	17.791	28.000	7.000	0.000	0.000	0.000
68	1.003	21.323	0.000	0.000	0.000	0.000	0.000
69	1.035	30.000	0.000	0.000	1148.11	-74.315	0.000
70	0.974	18.543	66.000	20.000	0.000	3.036	0.000
71	0.981	17.306	0.000	0.000	0.000	0.000	0.000
72	0.980	13.064	12.000	0.000	-12.000	-3.587	0.000
73	0.991	16.866	6.000	0.000	-6.000	22.814	0.000
74	0.948	17.792	68.000	27.000	0.000	0.587	0.000
75	0.960	19.107	47.000	11.000	0.000	0.000	0.000
76	0.943	16.563	68.000	36.000	0.000	11.602	0.000
77	1.006	19.768	61.000	28.000	0.000	47.696	0.000
78	1.002	19.331	71.000	26.000	0.000	0.000	0.000
79	1.004	19.361	39.000	32.000	0.000	0.000	0.000

80	1.040	20.689	130.000	26.000	477.000	121.036	0.000
81	0.996	21.105	0.000	0.000	0.000	0.000	0.000
82	0.980	16.824	54.000	27.000	0.000	0.000	0.000
83	0.978	16.986	20.000	10.000	0.000	0.000	0.000
84	0.978	17.756	11.000	7.000	0.000	0.000	0.000
85	0.985	18.454	24.000	15.000	0.000	3.977	0.000
86	0.987	17.084	21.000	10.000	0.000	0.000	0.000
87	1.015	17.344	0.000	0.000	4.000	11.022	0.000
88	0.988	20.194	48.000	10.000	0.000	0.000	0.000
89	1.005	23.295	0.000	0.000	607.000	-16.511	0.000
90	0.985	14.102	163.000	42.000	-85.000	91.847	0.000
91	0.980	15.126	10.000	0.000	-10.000	-11.252	0.000
92	0.993	17.974	65.000	10.000	0.000	-3.156	0.000
93	0.988	16.137	12.000	7.000	0.000	0.000	0.000
94	0.990	14.995	30.000	16.000	0.000	0.000	0.000
95	0.979	15.074	42.000	31.000	0.000	0.000	0.000
96	0.990	16.237	38.000	15.000	0.000	0.000	0.000
97	1.009	18.109	15.000	9.000	0.000	0.000	0.000
98	1.021	16.638	34.000	8.000	0.000	0.000	0.000
99	1.010	12.517	42.000	0.000	-42.000	-3.535	0.000
100	1.017	13.043	37.000	18.000	250.000	139.248	0.000
101	0.993	14.261	22.000	15.000	0.000	0.000	0.000
102	0.992	16.633	5.000	3.000	0.000	0.000	0.000
103	0.991	8.179	23.000	16.000	40.000	16.038	0.000
104	0.971	4.787	38.000	25.000	0.000	16.540	0.000
105	0.965	3.208	31.000	26.000	0.000	15.481	0.000
106	0.960	3.083	43.000	16.000	0.000	0.000	0.000

107	0.952	-1.190	50.000	12.000	-22.000	20.527	0.000
108	0.966	1.093	2.000	1.000	0.000	0.000	0.000
109	0.966	0.267	8.000	3.000	0.000	0.000	0.000
110	0.973	-1.560	39.000	30.000	0.000	20.579	0.000
111	0.980	0.085	0.000	0.000	36.000	-1.844	0.000
112	0.975	-6.628	68.000	13.000	-43.000	61.734	0.000
113	0.993	2.321	6.000	0.000	-6.000	0.996	0.000
114	0.961	3.342	8.000	3.000	0.000	0.000	0.000
115	0.961	3.324	22.000	7.000	0.000	0.000	0.000
116	1.005	20.460	184.000	0.000	-184.000	75.380	0.000
117	0.974	-1.200	20.000	8.000	0.000	0.000	0.000
118	0.945	17.456	33.000	15.000	0.000	0.000	0.000
Total			4242.000	1438.000	4433.11	1186.923	0.000

Line Flow and Losses

--Line-- Power at bus & line flow --Line loss-- Transformer

from to MW Mvar MVA MW Mvar tap

1 -51.000 -31.218 59.796

2 -12.855 -12.878 18.196 0.101 -2.025

3 -38.145 -18.340 42.325 0.251 -0.176

2 -20.000 -9.000 21.932

1 12.956 10.853 16.901 0.101 -2.025

12 -32.956 -19.853 38.474 0.288 -0.565

3 -39.000 -10.000 40.262

1 38.396 18.164 42.475 0.251 -0.176

5 -66.940 -16.270 68.889 1.209 2.657

12 -10.456 -11.894 15.837 0.108 -3.535

4	-48.000	-51.533	70.425			
5	-108.780	-51.050	120.163	0.255	0.946	
11	60.780	-0.483	60.782	0.775	0.832	
5	0.000	0.000	0.000			
4	109.035	51.995	120.798	0.255	0.946	
3	68.149	18.927	70.729	1.209	2.657	
6	86.069	8.307	86.469	0.884	2.594	
8	-337.953	-84.639	348.390	0.000	32.148	
11	74.699	5.409	74.895	1.132	2.081	
6	-52.000	-9.956	52.944			
5	-85.185	-5.713	85.376	0.884	2.594	
7	33.185	-4.243	33.455	0.052	-0.302	
7	-19.000	-2.000	19.105			
6	-33.132	3.941	33.366	0.052	-0.302	
12	14.132	-5.941	15.331	0.020	-0.776	
8	-56.000	56.180	79.323			
9	-440.635	-89.734	449.679	4.620	-65.305	
5	337.953	116.787	357.563	0.000	32.148	0.985
30	46.682	29.126	55.023	0.221	-48.865	
9	0.000	0.000	0.000			
8	445.255	24.429	445.924	4.620	-65.305	

10	-445.255	-24.429	445.924	4.745	-75.471
10	450.000	-51.042	452.886		
9	450.000	-51.042	452.886	4.745	-75.471
11	-70.000	-23.000	73.682		
4	-60.005	1.315	60.019	0.775	0.832
5	-73.568	-3.328	73.643	1.132	2.081
12	31.324	-30.254	43.548	0.115	-0.111
13	32.249	9.266	33.554	0.262	-0.937
12	38.000	72.315	81.691		
11	-31.208	30.143	43.389	0.115	-0.111
2	33.243	19.288	38.434	0.288	-0.565
3	10.564	8.359	13.471	0.108	-3.535
7	-14.112	5.165	15.028	0.020	-0.776
14	15.116	-0.198	15.117	0.050	-1.608
16	4.245	4.360	6.086	0.010	-2.046
117	20.153	5.197	20.812	0.153	
13	-34.000	-16.000	37.577		
11	-31.987	-10.203	33.575	0.262	-0.937
15	-2.013	-5.797	6.136	0.010	-5.935
14	-14.000	-1.000	14.036		
12	-15.066	-1.410	15.131	0.050	-1.608
15	1.066	0.410	1.142	0.006	-4.834

15		-90.000	0.434	90.001	
13	2.022	-0.138	2.027	0.010	-5.935
14	-1.060	-5.244	5.350	0.006	-4.834
17	-104.725	-6.808	104.946	1.510	0.660
19	7.751	14.567	16.501	0.036	-0.845
33	6.012	-1.944	6.318	0.014	-3.015
16		-25.000	-10.000	26.926	
12	-4.235	-6.406	7.679	0.010	-2.046
17	-20.765	-3.594	21.074	0.203	-3.771
17		-11.000	-3.000	11.402	
15	106.236	7.468	106.498	1.510	0.660
16	20.968	-0.177	20.969	0.203	-3.771
18	79.268	29.295	84.508	0.888	2.386
30	-235.853	-65.107	244.675	0.000	23.356
31	13.064	13.416	18.725	0.194	-3.209
113	5.318	12.105	13.222	0.017	-0.705
18		-60.000	-31.525	67.778	
17	-78.380	-26.909	82.871	0.888	2.386
19	18.380	-4.615	18.951	0.042	-0.897
19		-45.000	-9.645	46.022	
18	-18.338	3.719	18.711	0.042	-0.897
20	-14.138	8.680	16.590	0.080	-2.425

15	-7.715	-15.413	17.236	0.036	-0.845
34	-4.809	-6.631	8.191	0.029	-5.969
20		-18.000	-3.000	18.248	
19	14.218	-11.105	18.041	0.080	-2.425
21	-32.218	8.105	33.222	0.220	-0.985
21		-14.000	-8.000	16.125	
20	32.438	-9.090	33.688	0.220	-0.985
22	-46.438	1.090	46.451	0.487	-0.045
22		-10.000	-5.000	11.180	
21	46.925	-1.134	46.939	0.487	-0.045
23	-56.925	-3.866	57.056	1.174	1.528
23		-7.000	-3.000	7.616	
22	58.099	5.394	58.349	1.174	1.528
24	-16.441	17.933	24.329	0.093	-4.601
25	-151.922	-29.198	154.703	3.699	9.887
32	103.264	2.871	103.304	3.406	1.076
24		-26.000	-14.045	29.551	
23	16.534	-22.534	27.949	0.093	-4.601
70	-29.591	1.357	29.622	0.021	-6.024
72	-12.943	7.131	14.777	0.128	-4.230
25		220.000	50.421	225.704	
23	155.621	39.085	160.454	3.699	9.887

26 -83.331 -18.848 85.436 -0.000 2.529

27 147.710 30.183 150.762 6.752 16.623

26 314.000 10.274 314.168

25 83.331 21.377 86.029 -0.000 2.529 0.960

30 230.669 -11.103 230.936 4.225 -45.398

27 -80.000 -7.936 80.393

25 -140.957 -13.560 141.608 6.752 16.623

28 32.621 -0.544 32.626 0.217 -1.039

32 9.302 1.435 9.412 0.022 -1.723

115 19.034 4.733 19.614 0.069 -1.522

28 -17.000 -7.000 18.385

27 -32.404 -0.495 32.408 0.217 -1.039

29 15.404 -6.505 16.721 0.068 -1.933

29 -24.000 -4.000 24.331

28 -15.336 4.572 16.003 0.068 -1.933

31 -8.664 -8.572 12.188 0.017 -0.722

30 0.000 0.000 0.000

17 235.853 88.463 251.898 0.000 23.356 0.960

8 -46.462 -77.991 90.782 0.221 -48.86

26 -226.444 -34.295 229.026 4.225 -45.398

38 37.052 23.823 44.050 0.159 -38.079

31 -36.000 3.300 36.151

	17	-12.869	-16.624	21.023	0.194	-3.209
	29	8.681	7.850	11.704	0.017	-0.722
	32	-31.812	12.074	34.026	0.378	-1.089
32		-59.000	-34.169	68.180		
	23	-99.858	-1.795	99.874	3.406	1.076
	31	32.190	-13.163	34.777	0.378	-1.089
	27	-9.279	-3.158	9.802	0.022	-1.723
	113	6.894	-18.123	19.390	0.195	-4.317
	114	11.054	2.069	11.246	0.019	-1.422
33		-23.000	-9.000	24.698		
	15	-5.997	-1.071	6.092	0.014	-3.015
	37	-17.003	-7.929	18.761	0.142	-3.076
34		-59.000	-82.994	101.828		
	19	4.838	0.662	4.883	0.029	-5.969
	36	30.857	-24.814	39.597	0.139	-0.126
	37	-81.194	-68.875	106.472	0.297	0.125
	43	-13.501	10.033	16.821	0.139	-3.481
35		-33.000	-9.000	34.205		
	36	0.282	-5.626	5.633	0.001	-0.259
	37	-33.282	-3.374	33.453	0.125	-0.731
36		-31.000	30.054	43.177		
	35	-0.282	5.366	5.374	0.001	-0.259
	34	-30.718	24.688	39.410	0.139	-0.126

37 0.000 0.000 0.000

35 33.408 2.643 33.512 0.125 -0.731

33 17.144 4.853 17.818 0.142 -3.076

34 81.491 68.999 106.779 0.297 0.125

38 -278.623 -70.184 287.326 0.000 31.293

39 79.044 0.813 79.048 2.029 4.092

40 67.535 -7.125 67.910 2.749 3.735

38 0.000 0.000 0.000

37 278.623 101.477 296.527 0.000 31.293 0.935

30 -36.893 -61.903 72.063 0.159 -38.079

65 -241.730 -39.574 244.948 5.723 -38.376

39 -27.000 -11.000 29.155

37 -77.015 3.279 77.085 2.029 4.092

40 50.015 -14.279 52.014 0.525 0.264

40 -112.000 20.574 113.874

37 -64.786 10.860 65.690 2.749 3.735

39 -49.491 14.543 51.583 0.525 0.264

41 14.782 1.399 14.849 0.034 -1.031

42 -12.506 -6.228 13.971 0.102 -4.117

41 -37.000 -10.000 38.328

40 -14.748 -2.430 14.947 0.034 -1.031

42 -22.252 -7.570 23.504 0.233 -2.510

42 -155.000 49.834 162.814

40	12.608	2.111	12.783	0.102	-4.117
41	22.485	5.060	23.047	0.233	-2.510
49	-95.046	21.332	97.411	7.137	23.550
49	-95.046	21.332	97.411	7.137	23.550
43		-18.000	-7.000	19.313	
44	-31.640	6.513	32.304	0.702	-2.894
34	13.640	-13.513	19.201	0.139	-3.481
44		3.000	-8.000	8.544	
43	32.342	-9.408	33.682	0.702	-2.894
45	-29.342	1.408	29.376	0.206	-1.296
45		-53.000	-22.000	57.385	
44	29.548	-2.704	29.671	0.206	-1.296
46	-32.927	-11.956	35.030	0.500	-1.563
49	-49.621	-7.340	50.161	1.787	0.411
46		-28.000	15.122	31.822	
45	33.427	10.393	35.005	0.500	-1.563
47	-44.861	6.601	45.344	0.782	-0.603
48	-16.566	-1.873	16.671	0.163	-4.298
47		-34.000	0.000	34.000	
46	45.643	-7.205	46.209	0.782	-0.603

49	12.306	-23.332	26.378	0.122	-1.266
69	-91.949	30.536	96.887	7.909	18.591
48	-20.000	-11.000	22.825		
46	16.729	-2.426	16.904	0.163	-4.298
49	-36.729	-8.574	37.717	0.246	-0.615
49	117.000	143.422	185.092		
47	-12.183	22.066	25.206	0.122	-1.266
42	102.183	2.219	102.207	7.137	23.550
42	102.183	2.219	102.207	7.137	23.550
45	51.408	7.751	51.989	1.787	0.411
48	36.975	7.959	37.822	0.246	-0.615
50	52.880	13.603	54.602	0.765	0.230
51	65.686	20.626	68.848	2.228	2.886
54	36.928	13.196	39.215	1.150	-2.689
54	36.927	11.357	38.634	1.319	-2.747
66	-137.121	5.893	137.248	3.230	13.822
66	-137.121	5.893	137.248	3.230	13.822
69	-81.743	30.640	87.297	7.412	15.597
50	-17.000	-4.000	17.464		
49	-52.116	-13.373	53.804	0.765	0.230
57	35.116	9.373	36.345	0.641	-1.416

51		-17.000	-8.000	18.788	
49	-63.457	-17.739	65.890	2.228	2.886
52	28.270	6.331	28.970	0.184	-0.759
58	18.187	3.409	18.504	0.095	-1.390
52		-18.000	-5.000	18.682	
51	-28.086	-7.089	28.967	0.184	-0.759
53	10.086	2.089	10.300	0.052	-3.464
53		-23.000	-11.000	25.495	
52	-10.034	-5.553	11.468	0.052	-3.464
54	-12.966	-5.447	14.063	0.054	-2.549
54		-65.000	-28.269	70.881	
53	13.020	2.897	13.339	0.054	-2.549
49	-35.777	-15.886	39.146	1.150	-2.689
49	-35.609	-14.105	38.300	1.319	-2.747
55	6.836	1.512	7.001	0.010	-1.796
56	17.781	4.560	18.356	0.010	-0.631
59	-31.250	-7.249	32.080	0.550	-3.121
55		-63.000	-17.337	65.342	
54	-6.826	-3.308	7.585	0.010	-1.796
56	-20.820	-6.020	21.673	0.025	-0.262
59	-35.354	-8.008	36.250	0.669	-2.251
51	-28.086	-7.089	28.967	0.184	-0.759

53	10.086	2.089	10.300	0.052	-3.464
53	-23.000	-11.000	25.495		
51	-17.000	-8.000	18.788		
49	-63.457	-17.739	65.890	2.228	2.886
52	28.270	6.331	28.970	0.184	-0.759
58	18.187	3.409	18.504	0.095	-1.390

52	-10.034	-5.553	11.468	0.052	-3.464
54	-12.966	-5.447	14.063	0.054	-2.549
54	-65.000	-28.269	70.881		
53	13.020	2.897	13.339	0.054	-2.549
49	-35.777	-15.886	39.146	1.150	-2.689
49	-35.609	-14.105	38.300	1.319	-2.747
55	6.836	1.512	7.001	0.010	-1.796
56	-84.000	-20.299	86.418		
54	-17.771	-5.191	18.513	0.010	-0.631

55	20.845	5.759	21.626	0.025	-0.262
57	-22.262	-9.431	24.177	0.213	-1.642
59	-30.060	-3.592	30.274	0.798	-2.663
57		-12.000	-3.000	12.369	
56	22.475	7.789	23.786	0.213	-1.642
50	-34.475	-10.789	36.124	0.641	-1.416
58		-12.000	-3.000	12.369	
56	6.092	1.799	6.352	0.017	-2.166
51	-18.092	-4.799	18.717	0.095	-1.390
59		-122.000	-36.070	127.220	

54	31.800	4.128	32.067	0.550	-3.121
56	29.425	0.801	29.436	0.747	-3.077
56	30.859	0.929	30.873	0.798	-2.663
55	36.023	5.757	36.480	0.669	-2.251
60	-43.798	3.715	43.955	0.637	-0.766
61	-52.247	5.194	52.505	0.940	0.495
63	-154.061	-56.595	164.128	0.000	10.717
60		-78.000	-3.000	78.058	
59	44.435	-4.481	44.660	0.637	-0.766
61	-112.809	8.656	113.141	0.343	0.315
62	-9.626	-7.174	12.005	0.017	-1.379
61		160.000	-40.366	165.013	
59	53.187	-4.699	53.394	0.940	0.495
60	113.152	-8.341	113.459	0.343	0.315
62	26.130	-13.990	29.639	0.072	-0.645
64	-32.469	-13.336	35.101	-0.000	0.334
62		-77.000	-12.792	78.055	
60	9.642	5.796	11.250	0.017	-1.379

61 -26.058 13.345 29.276 0.072 -0.645

66 -36.721 -17.395 40.633 0.755 -2.652

67 -23.864 -14.537 27.943 0.191 -2.288

63 0.000 0.000 0.000

59 154.061 67.312 168.124 0.000 10.717 0.960

64 -154.061 -67.312 168.124 0.495 -14.826

64 0.000 0.000 0.000

63 154.556 52.486 163.225 0.495 -14.826

61 32.469 13.669 35.229 -0.000 0.334 0.985

65 -187.025 -66.155 198.381 1.036 -25.944

65 391.000 99.828 403.543

38 247.452 1.198 247.455 5.723 -38.376

64 188.061 40.211 192.312 1.036 -25.944

66 17.886 72.290 74.470 0.000 1.776 0.935

68 -62.400 -13.871 63.923 0.058 -63.641

66 353.000 -20.580 353.599

49 140.352 7.929 140.575 3.230 13.822

49 140.352 7.929 140.575 3.230 13.822

62 37.476 14.743 40.271 0.755 -2.652

65 -17.886 -70.514 72.747 0.000 1.776

67 52.707 19.333 56.141 0.652 0.084

67 -28.000 -7.000 28.862

62 24.055 12.249 26.994 0.191 -2.288

66 -52.055 -19.249 55.500 0.652 0.084

68 0.000 0.000 0.000

65 62.458 -49.770 79.862 0.058 -63.641

69 -452.673 143.681 474.928 0.000 72.525 0.935

81 21.736 -7.711 23.063 0.027 -80.405

116 368.479 -86.201 378.428 0.479 -10.820

69 1148.113 -74.315 1150.515

47 99.858 -11.945 100.570 7.909 18.591

49 89.156 -15.043 90.416 7.412 15.597

68 452.673 -71.156 458.231 0.000 72.525

70 163.998 20.255 165.244 7.733 20.416

75 162.082 18.196 163.100 10.165 18.271

77 180.346 -14.623 180.938 9.406 19.931

70 -66.000 -16.964 68.145

69 -156.265 0.160 156.265 7.733 20.416

24 29.612 -7.380 30.518 0.021 -6.024

71 50.145 -32.444 59.725 0.329 0.486

74 13.711 13.448 19.205 0.175 -2.533

75 -3.202 9.252 9.790 0.059 -3.171

71	0.000	0.000	0.000		
70	-49.815	32.929	59.715	0.329	0.486
72	37.755	-9.289	38.880	0.684	-1.514
73	12.061	-23.640	26.539	0.061	-0.826
72	-24.000	-3.587	24.267		
24	13.071	-11.361	17.318	0.128	-4.230
71	-37.071	7.774	37.877	0.684	-1.514
73	-12.000	22.814	25.778		
71	-12.000	22.814	25.778	0.061	-0.826
74	-68.000	-26.413	72.950		
70	-13.536	-15.981	20.943	0.175	-2.533
75	-54.464	-10.432	55.454	0.420	0.444
75	-47.000	-11.000	48.270		
70	3.261	-12.423	12.844	0.059	-3.171
69	-151.917	0.075	151.917	10.165	18.271
74	54.884	10.877	55.951	0.420	0.444
77	-11.243	-21.159	23.960	0.315	-3.764
118	58.015	11.630	59.169	0.553	0.749
76	-68.000	-24.398	72.244		
77	-43.651	-27.680	51.687	1.290	0.802
118	-24.349	3.282	24.569	0.112	-0.837
77	-61.000	19.696	64.101		
76	44.941	28.481	53.206	1.290	0.802
69	-170.941	34.554	174.398	9.406	19.931

75	11.558	17.395	20.885	0.315	-3.764
78	66.736	14.871	68.372	0.174	-0.698
80	-52.810	-54.123	75.619	0.918	-2.322
80	-23.277	-27.083	35.711	0.353	-1.127
82	62.794	5.600	63.043	1.189	-4.662
78		-71.000	-26.000	75.611	
77	-66.561	-15.569	68.358	0.174	-0.698
79	-4.439	-10.431	11.336	0.007	-0.622
79		-39.000	-32.000	50.448	
78	4.445	9.809	10.769	0.007	-0.622
80	-43.445	-41.809	60.295	0.550	0.529
80		347.000	95.036	359.779	
77	53.728	51.801	74.633	0.918	-2.322
77	23.630	25.956	35.101	0.353	-1.127
79	43.996	42.337	61.058	0.550	0.529
81	-21.709	-70.817	74.070	0.000	1.877
96	48.004	18.205	51.340	0.902	-0.482
97	55.398	23.093	60.019	0.621	0.500
98	70.556	3.266	70.631	1.101	1.955
99	73.396	1.195	73.406	2.268	4.555
81		0.000	0.000	0.000	

	68	-21.709	-72.694	75.866	0.027	-80.405
80	21.709	72.694	75.866	0.000	1.877	0.935
82		-54.000	-27.000	60.374		
	77	-61.605	-10.261	62.454	1.189	-4.662
	83	-4.637	7.250	8.606	0.012	-3.599
	96	12.242	-23.989	26.932	0.102	-4.946
83		-20.000	-10.000	22.361		
	82	4.649	-10.849	11.803	0.012	-3.599
	84	-8.028	2.371	8.371	0.051	-2.360
	85	-16.621	-1.522	16.690	0.124	-2.923
84		-11.000	-7.000	13.038		
	83	8.079	-4.731	9.362	0.051	-2.360
	85	-19.079	-2.269	19.214	0.116	-0.943
85		-24.000	-11.023	26.410		
	83	16.745	-1.401	16.804	0.124	-2.923
	84	19.195	1.327	19.241	0.116	-0.943
	86	17.172	-7.354	18.681	0.119	-2.263
	88	-28.463	1.311	28.493	0.168	-1.828
	89	-48.650	-4.905	48.896	0.585	-0.421
86		-21.000	-10.000	23.259		

85	-17.053	5.091	17.797	0.119	-2.263
87	-3.947	-15.091	15.599	0.053	-4.069
87	4.000	11.022	11.725		
86	4.000	11.022	11.725	0.053	-4.069
88	-48.000	-10.000	49.031		
85	28.631	-3.139	28.803	0.168	-1.828
89	-76.631	-6.861	76.938	0.840	2.383
89	607.000	-16.511	607.225		
85	49.234	4.484	49.438	0.585	-0.421
88	77.472	9.244	78.021	0.840	2.383
90	82.656	-7.986	83.041	3.518	7.542
92	57.549	-6.048	57.866	1.295	1.077
90	-248.000	49.847	252.960		
89	-79.138	15.528	80.647	3.518	7.542
89	-151.656	24.054	153.551	5.851	14.015
91	-17.207	10.265	20.036	0.111	-1.701
91	-20.000	-11.252	22.948		
90	157.506	-10.039	157.826	5.851	14.015
92	182.582	-6.165	182.686	3.269	11.204
90	17.318	-11.966	21.050	0.111	-1.701
92	-37.318	0.714	37.324	0.563	-1.329
92	-65.000	-13.156	66.318		

89	-179.314	17.369	180.153	3.269	11.204
89	-56.254	7.125	56.704	1.295	1.077
91	37.881	-2.043	37.936	0.563	-1.329
93	35.850	-5.118	36.214	0.341	-1.019
94	30.339	-8.563	31.524	0.470	-2.448
100	26.645	-14.992	30.573	0.572	-2.164
102	39.853	-6.935	40.452	0.203	-0.520
93		-12.000	-7.000	13.892	
92	-35.510	4.099	35.745	0.341	-1.019
94	23.510	-11.099	25.998	0.150	-1.342
94		-30.000	-16.000	34.000	
92	-29.869	6.115	30.488	0.470	-2.448
93	-23.360	9.757	25.315	0.150	-1.342
95	3.985	22.672	23.019	0.075	-0.831
96	-22.208	6.080	23.025	0.150	-1.771
100	41.451	-60.624	73.440	0.916	-3.100
95		-42.000	-31.000	52.202	
94	-3.911	-23.502	23.826	0.075	-0.831
96	-38.089	-7.498	38.820	0.267	-0.576
96		-38.000	-15.000	40.853	

94	22.358	-7.852	23.696	0.150	-1.771
95	38.356	6.922	38.976	0.267	-0.576
97	-39.472	-14.427	42.026	0.306	-0.833
97	-15.000	-9.000	17.493		
80	-54.778	-22.593	59.254	0.621	0.500
96	39.778	13.593	42.036	0.306	-0.833
98	-34.000	-8.000	34.928		
80	-69.455	-1.311	69.468	1.101	1.955
100	35.455	-6.689	36.081	0.485	-2.75
99	-84.000	-3.535	84.074		
80	-71.128	3.360	71.207	2.268	4.555
100	-12.872	-6.895	14.602	0.035	-2.060
100	213.000	121.248	245.092		
92	-26.073	12.827	29.058	0.572	-2.164
94	-40.535	57.524	70.371	0.916	-3.100
98	-34.970	3.932	35.191	0.485	-2.757
99	12.907	4.835	13.783	0.035	-2.060
101	-12.163	20.423	23.771	0.171	-2.536
103	164.914	4.248	164.969	4.215	8.426
104	72.156	9.198	72.740	2.333	5.205
106	76.764	8.261	77.208	3.524	7.275
101	-22.000	-15.000	26.627		

100	12.334	-22.959	26.063	0.171	-2.536
102	-34.334	7.959	35.244	0.316	-1.457
102		-5.000	-3.000	5.831	
92	-39.650	6.416	40.166	0.203	-0.520
101	34.650	-9.416	35.907	0.316	-1.457
103		17.000	0.038	17.000	
100	-160.699	4.178	160.754	4.215	8.426
104	36.748	0.767	36.756	0.644	-1.727
105	51.371	-0.847	51.378	1.438	0.466
110	89.580	-4.060	89.672	3.193	10.374
104		-38.000	-8.460	38.930	
100	-69.823	-3.993	69.937	2.333	5.205
103	-36.104	-2.494	36.190	0.644	-1.727
105	67.927	-1.973	67.955	0.487	0.927
105		-31.000	-10.519	32.736	
103	-49.932	1.313	49.950	1.438	0.466
104	-67.440	2.899	67.502	0.487	0.927
106	5.594	6.762	8.775	0.013	-1.278
107	37.745	-4.796	38.048	0.815	-1.524
108	43.034	-16.696	46.160	0.589	-0.131
106		-43.000	-16.000	45.880	

100	-73.241	-0.986	73.247	3.524	7.275
105	-5.581	-8.039	9.786	0.013	-1.278
107	35.821	-6.975	36.494	0.751	-1.720
107	-72.000	8.527	72.503		
105	-36.930	3.272	37.075	0.815	-1.524
106	-35.070	5.255	35.461	0.751	-1.720
108	-2.000	-1.000	2.236		
105	-42.445	16.566	45.563	0.589	-0.131
109	40.445	-17.566	44.095	0.218	-0.112
109	-8.000	-3.000	8.544		
108	-40.227	17.453	43.850	0.218	-0.112
110	32.227	-20.453	38.170	0.422	-0.741
110	-39.000	-9.421	40.122		
103	-86.388	14.434	87.585	3.193	10.374
109	-31.805	19.712	37.418	0.422	-0.741
111	-35.703	0.956	35.716	0.297	-0.888
112	114.895	-44.523	123.220	3.895	4.211
111	36.000	-1.844	36.047		
110	36.000	-1.844	36.047	0.297	-0.888
112	-111.000	48.734	121.227		

110	-111.000	48.734	121.227	3.895	4.211
113	-12.000	0.996	12.041		
114	-3.035	-0.745	3.125	0.000	-0.254
116	-368.000	75.380	375.641		
68	-368.000	75.380	375.641	0.479	-10.820
117	-20.000	-8.000	21.541		
12	-20.000	-8.000	21.541	0.153	-2.803
118	-33.000	-15.000	36.249		
75	-57.461	-10.881	58.483	0.553	0.749
76	24.461	-4.119	24.806	0.112	-0.837
Total loss				191.113	-251.076

Conclusion

In additional to discussing how load flow studies are made by computer in this book represented the two methods of controlling voltage and the flow of power from standpoint of understanding how this control is accomplished.

The load flow study on a computer is the best way to obtain quantitative answers for the effect of specific control.

Conversion of impedance to admittance because of data preparation is simple it's formulation and modification is simple .using acceleration factor can be increased the rate of convergence.

Acceleration factor is a multiplier constant that enhances correction between the values of voltage in two successive iterations. Study the real, reactive power as well as voltage magnitude and phase angle. Using tap changing transformer for propose of voltage control.

Analysis of 30 bus system as well as 118 bus system and finding the real and reactive power and the total loss of the line .using matlab as well as ETP where we did in matlab and our future plane is for 2737 bus system using ETP the price of ETP is $39 so in this book we just did using matlab.

References

[1] power system analysis by Hadi Sadat

[2] Electrical power systems by Ashfaq Husain

[3] Modern power system Analysis -third adition by D P Kothari and I J Nagrath

[4] http://www.ee.washington.edu/research/pstca/pf118/ieee118cdf.txt

[5] http://www.ee.washington.edu/research/pstca/pf118/pg_tca118fig.htm

[6] http://www.ee.washington.edu/research/pstca/formats/cdf.txt

[7] http://www.ee.washington.edu/research/pstca/