ASSIGNMENT 1 EE330A 2020

GROUP.NO – 11

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Introduction

In the following project, our team solved the power flow problem using both MATLAB and Power world software. We computed the power flow solution using the Gauss-Seidel method in both the software. We verified our solution using both the software and find that they match very closely .

Problem Statement

Use the following data to solve the power flow problem using Gauss-Seidel method. Take bus 1 as the slack bus and base MVA as 100.

Build the system with the following data in Power World software. Present the power flow result from Power World software, using Gauss-Seidel method. How does it compare with the computed power flow solution?

What is the real power loss in the system? Can you reduce the real power loss by at least 5 MW by rescheduling the real power outputs of the generators? Verify your solution with the software, and show the results.

DATA FOR 5 BUS SYSTEM

Number	Nom (kV)	PU (Volt)	Angle (Deg)	Load (MW)	Load (Mvar)	Gen (MW)	Gen (Mvar)	B-Shunt (Mvar)
1	15	1	0	0	0	394.8	114.18	0
2	345	1	0	800	280	0	0	0
3	345	1.05	0	80	40	920	337.35	0
4	345	1	0	0	0	0	0	0
5	345	1	0	0	0	0	0	0

LINE DATA

From Number	To Number	Branch Device Type	R	X	B
5	1	Transformer	0.0015	0.02	0
4	2	Line	0.009	0.1	1.72
5	2	Line	0.0045	0.05	0.88
3	4	Transformer	0.00075	0.01	0
5	4	Line	0.00225	0.025	0.44

Results

Power Flow Solution for part (a)

MATLAB Solution

```
                  Gauss Seidel Load-Flow Study
                Report of Power Flow Calculations

25-Nov-2020
Number of iterations       : 75
Total real power losses    : 42.5934.
Total reactive power losses: 225.534.

                                        Generation           Load
      Bus      Volts     Angle      Real   Reactive      Real   Reactive
     1.0000    1.0000         0    2.5953  151.1791         0          0
     2.0000    0.8233  -16.3606         0         0  800.0000   280.0000
     3.0000    1.0500   11.3428  919.9985  394.3550   80.0000    40.0000
     4.0000    1.0132    6.9578         0         0         0          0
     5.0000    0.9697    0.1033         0         0         0          0

                      Line Flows
     #Line   From Bus    To Bus     Real    Reactive
     1.0000    5.0000    1.0000   -2.2524 -146.6068
     2.0000    4.0000    2.0000  350.8089  140.7150
     3.0000    5.0000    2.0000  480.0963  264.8954
     4.0000    3.0000    4.0000  839.9985  354.3550
     5.0000    5.0000    4.0000 -477.8439 -118.2886

     1.0000    1.0000    5.0000    2.5953  151.1791
     2.0000    2.0000    4.0000 -335.4225 -116.3343
     3.0000    2.0000    5.0000 -464.5777 -163.6656
     4.0000    4.0000    3.0000 -834.3443 -278.9659
     5.0000    4.0000    5.0000  483.5351  138.2509
```

 # real power in MW and reactive power in MVar

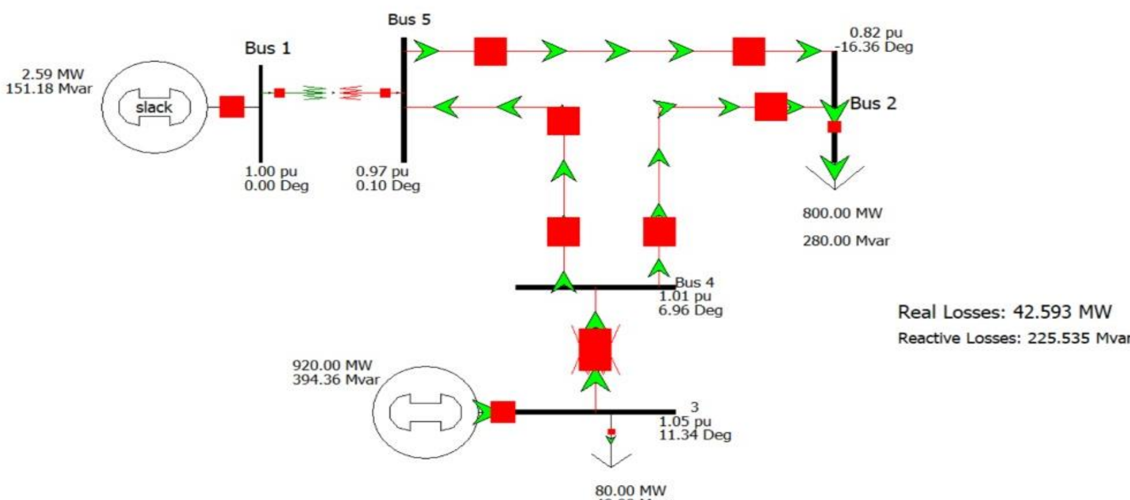

Figure 1. Five Bus system for part (a)

Filter Advanced Bus Find... Remove Quick Filter

	Number	Name	Area Name	Nom kV	PU Volt	Volt (kV)	Angle (Deg)	Load MW	Load Mvar	Gen MW	Gen Mvar	Switched Shunts Mvar
1	1	B1	1	15.00	1.00000	15.000	0.00			2.59	151.18	
2	2	2	1	345.00	0.82329	284.034	-16.36	800.00	280.00			
3	3	3	1	345.00	1.05000	362.250	11.34	80.00	40.00	920.00	394.36	
4	4	4	1	345.00	1.01322	349.560	6.96					
5	5	5	1	345.00	0.96973	334.556	0.10					

Conclusions:-

1. Total real power loss is 42.593 MW.
2. MVA rating of each Line/Transformer flow pie chart is 100 MVA.

Power Flow Solution for part (b)

MATLAB Solution

 # real power in MW and reactive power in MVar

```
              Gauss Seidel Load-Flow Study
           Report of Power Flow Calculations

 26-Nov-2020
 Number of iterations       : 73
 Total real power losses    : 35.0897.
 Total reactive power losses: 134.004.

                                    Generation             Load
      Bus       Volts      Angle      Real   Reactive      Real   Reactive
   1.0000      1.0000          0  315.0883   113.6161         0          0
   2.0000      0.8335   -21.1270         0          0  800.0000   280.0000
   3.0000      1.0500     1.7922  600.0010   340.3881   80.0000    40.0000
   4.0000      1.0188    -0.8733         0          0         0          0
   5.0000      0.9745    -3.6074         0          0         0          0

                     Line Flows
    #Line    From Bus    To Bus      Real    Reactive
   1.0000      5.0000    1.0000 -313.4055   -91.1783
   2.0000      4.0000    2.0000  313.1225   123.8684
   3.0000      5.0000    2.0000  516.3230   261.9582
   4.0000      3.0000    4.0000  520.0010   300.3881
   5.0000      5.0000    4.0000 -202.9175  -170.7799

   1.0000      1.0000    5.0000  315.0883   113.6161
   2.0000      2.0000    4.0000 -300.6819  -134.6389
   3.0000      2.0000    5.0000 -499.3180  -145.3611
   4.0000      4.0000    3.0000 -517.5478  -267.6775
   5.0000      4.0000    5.0000  204.4255   143.8091
```

Published with MATLAB® R2020b

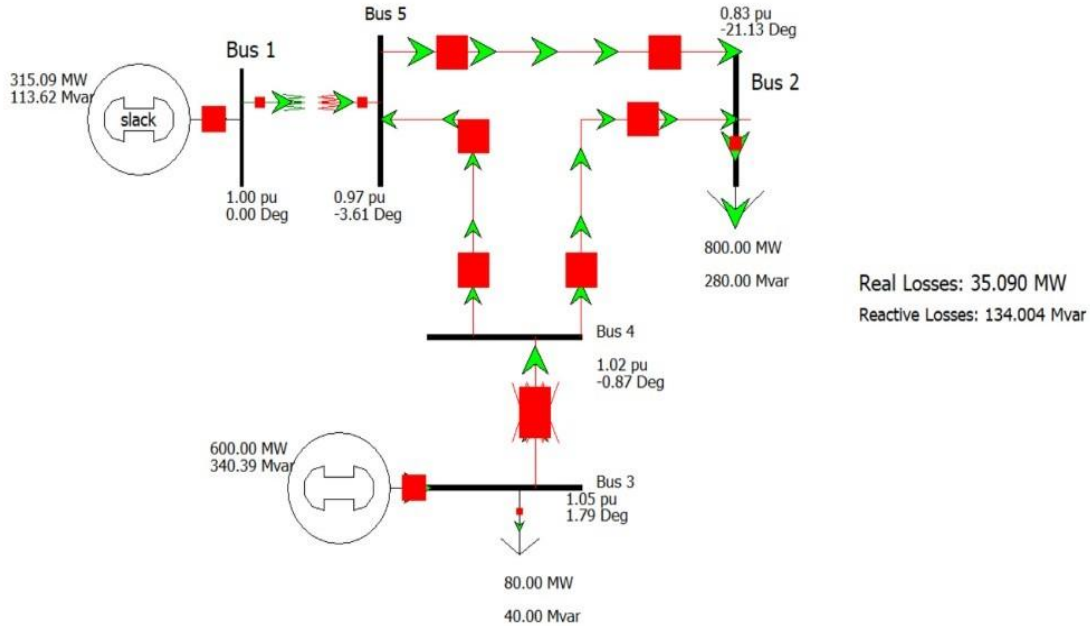

Figure 2. The Bus System after reducing initial/schedule real power at generator attached to bus 3

	Number	Name	Area Name	Nom kV	PU Volt	Volt (kV)	Angle (Deg)	Load MW	Load Mvar	Gen MW	Gen Mvar	Switched Shunts Mvar	Act G Shunt MW	Act B Shunt Mvar	Area Num	Zone Num
1	1	Bus 1	1	15.00	1.00000	15.000	0.00			315.09	113.62		0.00	0.00	1	1
2	2	Bus 2	1	345.00	0.83345	287.541	-21.13	800.00	280.00				0.00	0.00	1	1
3	3	Bus 3	1	345.00	1.05000	362.250	1.79	80.00	40.00	600.00	340.39		0.00	0.00	1	1
4	4	Bus 4	1	345.00	1.01878	351.479	-0.87						0.00	0.00	1	1
5	5	Bus 5	1	345.00	0.97448	336.196	-3.61						0.00	0.00	1	1

Observations

1. Yes, we can reduce the power loss by decreasing the initial/schedule real power at generator attached to bus 3. If we reduce initial/schedule real power to 600 MW instead of 920MW the total real power loss get reduced by 7MW satisfying the condition given in the question.
2. MVA rating of each Line/Transformer flow pie chart is 100 MVA.

MATLAB Code for part (a)

```
clear all; close all; clc
% Information about the bus matrix
% nd V Ang. Pg Qg PL QL Gs jBs Type
% (1) (2) (3) (4) (5) (6) (7) (8) (9) (10)
% Colum 11: if the bus has shunt element =1, if it hasnt shunt element =0
% nd V Ang. Pg Qg PL QL Gs jBs Type
bus = [ 1 1.0 0.0 3.948 1.1418 0.0 0.0 0.0 0.0 1 0.0;
2 1.0 0.0 0.0000 0.0000 8.0 2.80 0.0 0.0 3 0.0;
3 1.05 0.0 9.20 3.3735 0.8 0.40 0.0 0.0 2 0.0;
4 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 3 0.0;
5 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 3 0.0;];
%Information about the line matrix
%COL 1.- From bus
%COL 2.- to bus
%COL 3.- R P.U.
%COL 4.- Xl P.U.
%COL 5.- B (parallel) P.U.
%COL 6.- Type of line: 0==Line ; 1==Transformer
%COL 7.- phase shifter angle
line = [ 5 1 0.0015 0.02 0.00 1 0.0;
4 2 0.009 0.1 1.72 0 0.0;
5 2 0.0045 0.05 0.88 0 0.0;
3 4 0.00075 0.01 0.0 1 0.0;
5 4 0.00225 0.025 0.44 0 0.0;];
% Data of the power system is stored in the bus and line matrix of the
% following file
nbuses=length(bus(:,1)); % number of buses of the electric power system
V=bus(:,2); Vprev=V; % Initial bus voltages
The=bus(:,3); % Initial bus angles
% Net power (Generation - Load)
P=bus(:,4)-bus(:,6);
Q=bus(:,5)-bus(:,7);
% ++++++++++++++ First, compute the addmitance matrix Ybus ++++++++++++++++
[Y] = Y_admi(line,bus,nbuses); % function to get the admittance matrix


% +++++++++++++++++++++++ Start iterative process +++++++++++++++++++++++++
tolerance=1;
iteration=0;
while (tolerance > 1e-8)
for k=2:nbuses
PYV=0;
for i=1:nbuses
if k ~= i
PYV = PYV + Y(k,i)* V(i); % Vk * Yik
end
end
if bus(k,10)==2 % PV bus
% Estimate Qi at each iteration for the PV buses
Q(k)=-imag(conj(V(k))*(PYV + Y(k,k)*V(k)));
end
V(k) = (1/Y(k,k))*((P(k)-j*Q(k))/conj(V(k))-PYV); % Compute bus voltages
if bus(k,10) == 2 % For PV buses, the voltage magnitude remains same, but the angle changes
V(k)=abs(Vprev(k))*(cos(angle(V(k)))+j*sin(angle(V(k))));
```

```
end
end
iteration=iteration+1; % Increment iteration count
tolerance = max(abs(abs(V) - abs(Vprev))); % Tolerance at the current iteration
Vprev=V;
end


% Now, we have found V and Theta, then, we can compute the power flows


% ++++++++++++++++++++++++++++ Power flow +++++++++++++++++++++++++++++++
% currents at each node
I=Y*V;
% Power at each node
S=V.*conj(I); % Complex power
for k=1:nbuses
if bus(k,10)==1
% Real and reactive generation at the Slack bus
Pgen(k)=real(S(k));
Qgen(k)=imag(S(k));
end
if bus(k,10)==2
% Real and reactive generation at the PV buses
Pgen(k)=real(S(k))+bus(k,6);
Qgen(k)=imag(S(k))+bus(k,7);
end
if bus(k,10)==3
Pgen(k)=0;
Qgen(k)=0;
end
end
% calculate the line flows and power losses
FromNode=line(:,1);
ToNode=line(:,2);
nbranch=5;
for k=1:nbranch
a=line(k,6); % Find out if is a line or a transformer, a=0 -> line, a=1 -> transformer, 0<a<1 ->
Transformer
switch a % for both cases use the pi model
case 0 %if its a line a=0
b=1i*line(k,5);
suceptancia(k,1)=b/2;
suceptancia(k,2)=b/2;
otherwise %if its a transformer
Zpq=line(k,3)+1i*line(k,4);
Ypq=Zpq^-1;
suceptancia(k,1)=(Ypq/a)*((1/a)-1);
suceptancia(k,2)=Ypq*(1-(1/a));
end
end
% Define admmitance of lines
r = line(:,3);
rx = line(:,4);
z = r + j*rx;
y = ones(nbranch,1)./z;
% Define complex power flows
Ss = V(FromNode).*conj((V(FromNode) - V(ToNode)).*y ...
   + V(FromNode).*suceptancia(:,1)); % complex flow of the sending buses
```

```
Sr = V(ToNode).*conj((V(ToNode) - V(FromNode)).*y ...
   + V(ToNode).*suceptancia(:,2)); % complex flow of the receiving buses


% Define active and reactive power flows
Pij=real(Ss);
Qij=imag(Ss);
Pji=real(Sr);
Qji=imag(Sr);


% Active power lossess
P_loss=sum(Pij+Pji);


% Reactive power lossess
Q_loss=sum(Qij+Qji);


% +++++++++++++++++++++++++++ Print results +++++++++++++++++++++++++++++++
disp('                      Gauss Seidel Load-Flow Study')
disp('                    Report of Power Flow Calculations ')
disp(' ')
disp(date)
fprintf('Number of iterations       : %g \n', iteration)
fprintf('Total real power losses    : %g.\n',P_loss)
fprintf('Total reactive power losses: %g.\n\n',Q_loss)
disp('                                     Generation             Load')
disp('      Bus      Volts     Angle      Real  Reactive      Real  Reactive ')
ywz=[  bus(:,1)    abs(V)  (180/pi)*angle(V)  Pgen'  Qgen'  bus(:,6)  bus(:,7)];
disp(ywz)


disp('                      Line Flows                     ')
disp('    #Line    From Bus   To Bus     Real    Reactive   ')
l=1:1:nbranch;
xy=[l' FromNode ToNode Pij Qij];
yx=[l' ToNode  FromNode Pji Qji];
disp(xy)
disp(yx)
```

MATLAB SOLUTION FOR PART (B)

```
clear all; close all; clc
% Information about the bus matrix
% nd V Ang. Pg Qg PL QL Gs jBs Type
% (1) (2) (3) (4) (5) (6) (7) (8) (9) (10)
% Colum 11: if the bus has shunt element =1, if it hasnt shunt element =0
% nd V Ang. Pg Qg PL QL Gs jBs Type
bus = [ 1 1.0 0.0 3.948 1.1418 0.0 0.0 0.0 0.0 1 0.0;
2 1.0 0.0 0.0000 0.0000 8.0 2.80 0.0 0.0 3 0.0;
3 1.05 0.0 6.00 3.3735 0.8 0.40 0.0 0.0 2 0.0;
4 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 3 0.0;
```

```
5 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 3 0.0;];
%Information about the line matrix
%COL 1.- From bus
%COL 2.- to bus
%COL 3.- R P.U.
%COL 4.- Xl P.U.
%COL 5.- B (parallel) P.U.
%COL 6.- Type of line: 0==Line ; 1==Transformer
%COL 7.- phase shifter angle
line = [ 5 1 0.0015 0.02 0.00 1 0.0;
4 2 0.009 0.1 1.72 0 0.0;
5 2 0.0045 0.05 0.88 0 0.0;
3 4 0.00075 0.01 0.0 1 0.0;
5 4 0.00225 0.025 0.44 0 0.0;];
% Data of the power system is stored in the bus and line matrix of the
% following file
nbuses=length(bus(:,1)); % number of buses of the electric power system
V=bus(:,2); Vprev=V; % Initial bus voltages
The=bus(:,3); % Initial bus angles
% Net power (Generation - Load)
P=bus(:,4)-bus(:,6);
Q=bus(:,5)-bus(:,7);
% ++++++++++++++ First, compute the addmitance matrix Ybus ++++++++++++++++
[Y] = Y_admi(line,bus,nbuses); % function to get the admittance matrix


% +++++++++++++++++++++++ Start iterative process +++++++++++++++++++++++++
tolerance=1;
iteration=0;
while (tolerance > 1e-8)
for k=2:nbuses
PYV=0;
for i=1:nbuses
if k ~= i
PYV = PYV + Y(k,i)* V(i); % Vk * Yik
end
end
if bus(k,10)==2 % PV bus
% Estimate Qi at each iteration for the PV buses
Q(k)=-imag(conj(V(k))*(PYV + Y(k,k)*V(k)));
end
V(k) = (1/Y(k,k))*((P(k)-j*Q(k))/conj(V(k))-PYV); % Compute bus voltages
if bus(k,10) == 2 % For PV buses, the voltage magnitude remains same, but the angle changes
V(k)=abs(Vprev(k))*(cos(angle(V(k)))+j*sin(angle(V(k))));
end
end
iteration=iteration+1; % Increment iteration count
tolerance = max(abs(abs(V) - abs(Vprev))); % Tolerance at the current iteration
Vprev=V;
end


% Now, we have found V and Theta, then, we can compute the power flows


% +++++++++++++++++++++++++++++ Power flow ++++++++++++++++++++++++++++++++
% currents at each node
I=Y*V;
% Power at each node
```

```
S=V.*conj(I); % Complex power
for k=1:nbuses
if bus(k,10)==1
% Real and reactive generation at the Slack bus
Pgen(k)=real(S(k));
Qgen(k)=imag(S(k));
end
if bus(k,10)==2
% Real and reactive generation at the PV buses
Pgen(k)=real(S(k))+bus(k,6);
Qgen(k)=imag(S(k))+bus(k,7);
end
if bus(k,10)==3
Pgen(k)=0;
Qgen(k)=0;
end
end
% calculate the line flows and power losses
FromNode=line(:,1);
ToNode=line(:,2);
nbranch=5;
for k=1:nbranch
a=line(k,6); % Find out if is a line or a transformer, a=0 -> line, a=1 -> transformer, 0<a<1 ->
Transformer
switch a % for both cases use the pi model
case 0 %if its a line a=0
b=1i*line(k,5);
suceptancia(k,1)=b/2;
suceptancia(k,2)=b/2;
otherwise %if its a transformer
Zpq=line(k,3)+1i*line(k,4);
Ypq=Zpq^-1;
suceptancia(k,1)=(Ypq/a)*((1/a)-1);
suceptancia(k,2)=Ypq*(1-(1/a));
end
end
% Define admmitance of lines
r = line(:,3);
rx = line(:,4);
z = r + j*rx;
y = ones(nbranch,1)./z;
% Define complex power flows
Ss = V(FromNode).*conj((V(FromNode) - V(ToNode)).*y ...
   + V(FromNode).*suceptancia(:,1)); % complex flow of the sending buses
Sr = V(ToNode).*conj((V(ToNode) - V(FromNode)).*y ...
   + V(ToNode).*suceptancia(:,2)); % complex flow of the receiving buses


% Define active and reactive power flows
Pij=real(Ss);
Qij=imag(Ss);
Pji=real(Sr);
Qji=imag(Sr);


% Active power lossess
P_loss=sum(Pij+Pji);
```

```
% Reactive power lossess
Q_loss=sum(Qij+Qji);


% +++++++++++++++++++++++++++ Print results ++++++++++++++++++++++++++++++++
disp('                      Gauss Seidel Load-Flow Study')
disp('                    Report of Power Flow Calculations ')
disp(' ')
disp(date)
fprintf('Number of iterations       : %g \n', iteration)
fprintf('Total real power losses    : %g.\n',P_loss)
fprintf('Total reactive power losses: %g.\n\n',Q_loss)
disp('                                      Generation             Load')
disp('      Bus      Volts     Angle      Real  Reactive      Real  Reactive ')
ywz=[  bus(:,1)    abs(V)  (180/pi)*angle(V)  Pgen'  Qgen'  bus(:,6)  bus(:,7)];
disp(ywz)


disp('                      Line Flows                     ')
disp('    #Line    From Bus   To Bus     Real    Reactive   ')
l=1:1:nbranch;
xy=[l' FromNode ToNode Pij Qij];
yx=[l' ToNode  FromNode Pji Qji];
disp(xy)
disp(yx)
```

MATLAB CODE FOR Y ADMITTANCE

```
function [Y] = Y_admi(line,bus,nbuses)
%% Y_BUS Building
orden=zeros(1,nbuses);
Y=zeros(nbuses);
for k=1:nbuses
    orden(k)=k; % vector which contains the order of building according to the bus information
end
for p=1:length(line(:,1));
    BusP=find(orden==line(p,1));
    BusQ=find(orden==line(p,2));
    a=line(p,6); %Tap value for the  p iteration
    if a>0 % for transformers out of nominal position
    yl=(1/((line(p,3)+j*line(p,4)))); % line admittance
    Ad=(j*line(p,5)/2); % line charging
    Y(BusP,BusQ)=Y(BusP,BusQ)-yl/a; % a non diagonal element
    Y(BusQ,BusP)=Y(BusP,BusQ); % symmetry is  declared for elements out of the diagonal
    Y(BusP,BusP)=Y(BusP,BusP)+(yl/a)+((1/a)*(1/a-1)*yl)+Ad; %Equivalent admittance at the P-terminal
plus line charging
    Y(BusQ,BusQ)=Y(BusQ,BusQ)+(yl/a)+(1-1/a)*yl+Ad; %Equivalent admittance at the Q-terminal plus
line charging
    else % for lines
         yl=(1/((line(p,3)+j*line(p,4)))); % line admittance
         Ad=(j*line(p,5)/2);  % line charging
         Y(BusP,BusQ)=Y(BusP,BusQ)-yl; % a non diagonal element
         Y(BusQ,BusP)=Y(BusP,BusQ); % symmetry is  declared for elements out of the diagonal
         Y(BusP,BusP)=Y(BusP,BusP)+yl; % diagonal element
         Y(BusQ,BusQ)=Y(BusQ,BusQ)+yl; % diagonal element
         c=line(p,5); % line charging for the whole line
         if c>0
             Y(BusP,BusP)= Y(BusP,BusP)+Ad; %add value of line charging to the diagonal element
```

```
            Y(BusQ,BusQ)= Y(BusQ,BusQ)+Ad; %add value of line charging to the diagonal element
        end


    end
end
% Susceptance and conductance
for m=1:nbuses
    dir=find(orden==bus(m,1));
    Y(dir,dir)=Y(dir,dir)+bus(m,8)+j*bus(m,9); % add the shunt admittance
end
end
```

Conclusion

The results from Gauss-Seidel Method match closely with the solution obtained from the Power-World Software. Thus, the problem has been solved and verified by both the methods.

Acknowledgement

We would like to express our gratitude to Prof. Saikat Chakrabarti who presented us with the opportunity to work on this project where we learnt to solve the power flow problem using both MATLAB and Powerworld software. We would also like to acknowledge the cohesive efforts of each member of the team so that we could learn and apply our theoretical knowledge.