Experiment No. 05

5.1 Experiment Name

Generate an algorithm and write a program on load flow study of a given power system using Gauss-Seidel method

5.2 Objectives

- To become acquainted with the load flow study of a given power system
- To learn how to generate a MATLAB code for numerical analysis using Gauss-Seidel method
- To get familiar with the procedure of designing and analyzing a power system in MATLAB

5.3 Theory

A load flow study is a numerical analysis of the flow of electric power in any electrical system. Its goal is to determine the flow, current, voltage, real power, and reactive power in a system under any load conditions.

A single-phase model is used to solve a load flow problem because the system is assumed to be operating under balanced conditions. Each bus is associated with four quantities. These are voltage magnitudes $|\boldsymbol{V}|$, phase angle $\boldsymbol{\delta}$, real power $\boldsymbol{P}$ and reactive power $\boldsymbol{Q}$.

For a power system with n nodes the network equation can be given by the matrix equation

$$\boldsymbol{I = YV}$$

The current injected into the $\boldsymbol{i^{th}}$ node can be obtained as $\boldsymbol{I_i = \sum_{k=1}^{n} Y_{ik} V_{ik}}$

The power injected into the $\boldsymbol{i^{th}}$ node can be written as

$$\boldsymbol{S_i = P_i + jQ_i = \sum_{K=1}^{n} |V_i|\,|V_k||V_{ik}| \angle \delta_i - \theta_{ik} - \delta_k}$$

Hence, the real power, $\boldsymbol{P_i}$ = **Re**($\boldsymbol{S_i}$) = $\boldsymbol{\sum_{K=1}^{n} |V_i|\,|V_k||V_{ik}| \cos \delta_i - \theta_{ik} - \delta_k}$

The reactive power, $\boldsymbol{Q_i}$ = **Im**($\boldsymbol{S_i}$) = $\boldsymbol{-\sum_{K=1}^{n} |V_i|\,|V_k||V_{ik}| \sin \delta_i - \theta_{ik} - \delta_k}$

The node voltage of a system can be found using the following equation

$$\boldsymbol{V_i = \frac{1}{Y_{ii}} \left[\frac{S_i}{V_i} - \sum_{\substack{K=1 \\ K \neq i}}^{n} Y_{ik}^{*} V_k^{*}\right]} \qquad \text{[for } \boldsymbol{i} = 1,2,3\ldots\ldots \boldsymbol{n}\text{]}$$

5.4 Required apparatus

- MATLAB

5.5 Block diagram

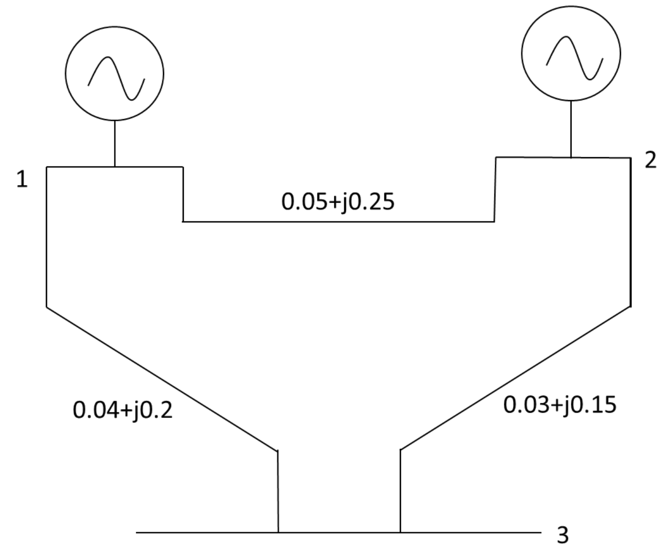


Fig. 5.1: Diagram of a three- bus system

5.6 Data table

Bus	Bus	R	X
1	1	0	1
1	2	0.05	0.25
1	3	0.04	0.02
2	2	0	1
2	3	0.03	0.15

Fig. 5.1 Excel file of the Impedance data

Bus	|v|	Pg	Qg	Pl	Ql	Angle
1	1.03	0	0	0	0	0
2	1.02	0.8	0	0.4	0.3	0
3	1	0	0	1	0.8	0

Fig. 5.2 Excel file of the Load data

5.7 Algorithm

1. Start
2. Read an excel file for taking input data and locate it
3. Generate a Y-bus matrix
4. Read node data. For P-V nodes take the starting values of the voltages as

   $$V_k^0 = V_k^0 \angle 0^0 \text{ for k=1,2,3......m.}$$

5. For load nodes take the starting values as $V_k^0 = 1.0\angle 0^0$ for k= m+1, m+2......
6. Start iteration count $i = 0$ and node number $k = 2$
7. If $k>m$, proceed to step 10, else move on to 9
8. As this is a P-V bus bar, compute the reactive power injection as follows

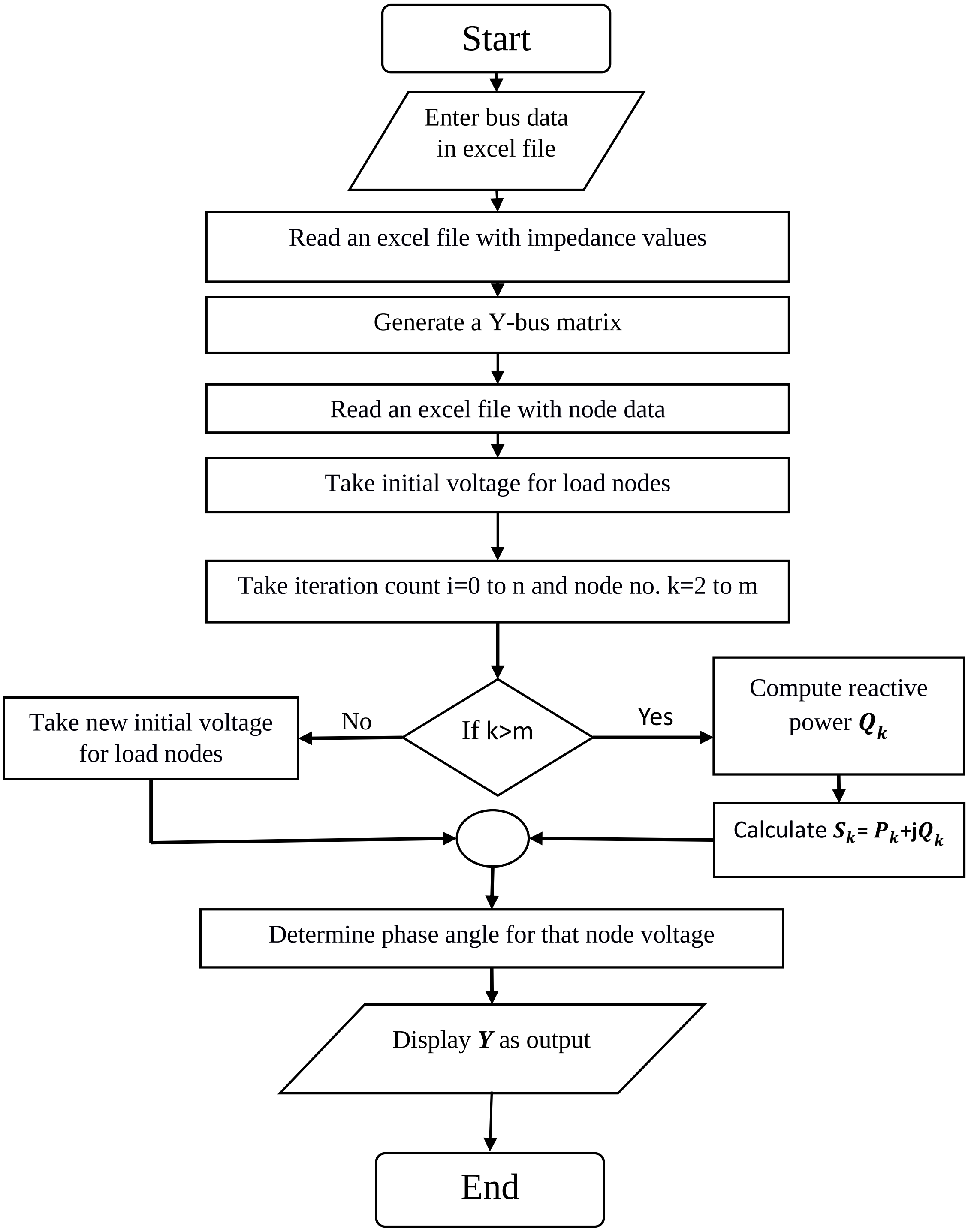
   $$Q_k = \text{Im}(S_k) = \text{Im}\,[\sum_{l=1}^{k-1} V_k^i\, Y_{kl}^* (V_k^{i+1})^* + \sum_{l=k}^{n} V_k^i\, Y_{kl}^* (V_k^i)^*]$$

9. Calculate $S_k = P_k + jQ_k$
10. Calculate the new value of voltage as follows

    $$V_k^{i+1} = \frac{1}{Y_{kk}}\,[\frac{S_k^*}{(V_k^i)^*} - \sum_{l=1}^{k-1} Y_{kl}\, V_l^{i+1} - \sum_{l=k+1}^{n} Y_{kl}\, V_l^i]$$

11. If $k>m$, proceed to step 14, else move to step 13
12. For P-V node and $|V_k^\delta|$ has already calculated, determine the phase angle from the value of V_k obtained in the above equation $\delta_k = \tan^{-1}[ImV_k^{i+1}/Re\ (V_k^{i+1})$ and compute the voltage at this node as $V_k^{i+1} = |V_k^\delta|\angle\delta_k$
13. If $k<n$ go to step 15 otherwise go to step 16
14. Take $k = K+1$ and go to step 8
15. If $|V_k^{i+1} - V_k^i|$ for all k = 2,3,4…. n is within tolerance limit, proceed to step 18, else go to step 17.
16. Take $i = i+1$ and go to step 7.
17. If $Pg\sim \leftarrow 0, V_k \leftarrow V_{o_k} e^{ia_{ng}}$ and $E <\leftarrow 10^{-3}$ break
18. Display output
19. End

5.8 Flow chart



5.9 MATLAB Code & Output

```
clc;  %Clears previous data from command window
clear all; %Removes all variables from the current workspace
cd('F:\Study material\Lab\3-2\Power System I'); %change the file directory
A = xlsread('EXp02p02'); %Read the excel file
n = length(A); %Determine the length of the excel file

% Applying symmetric condition
for w=1:n
    Z(A(w,1),A(w,2)) = A(w,3)+i*A(w,4);
    Z(A(w,2),A(w,1)) = A(w,3)+i*A(w,4);
end

m = length(Z); %Determine the length of the new matrix
for j=1:m
    for k=1:m
        if Z(j,k) == 0
            Z(j,k) = inf;
        end
    end
end
fprintf(' Z matrix is \n') %Display the text
disp(Z) %Display the output
y = 1./Z %Taking inverse impedance matrix
p = sum(y,2) %Taking symmetric summation

%Apply looping condition to determine value of the matrix element
for u=1:m
    for x=1:m
        if u~=x
            Y(u,x)= -y(u,x); %For diagonal element
        else
            Y(u,x)= p(x); %For non-diagonal element
        end
    end
end
fprintf(' Y- bus matrix is \n') %Display the text
disp(Y) %Display the output

cd('F:\Study material\Lab\3-2\Power System I'); %change the file directory
B = xlsread('Exp05'); %Read the excel file
j = 3;
V = B(:,2);
V0=B(:,2);

%to get the value of real power
P=B(:,3)-B(:,5);

%to get the value of reactive power
Q=B(:,4)-B(:,6);

%to get the angle
ang=B(:,7);
V1=V;

% to get the value of generator bus
Pg=B(:,3);
for w=1:100
    z=V;
    for k=2:j
```

```
        yv1=0;
        yv2=0;
        for h=1:j
            yv2=yv2+Y(k,h)*V(h); %to find the product of Y bus and voltages
            if h~=k
                yv1=yv1+Y(k,h)*V(h); %to find the product of Y bus and
voltages
            end
        end
        if Pg(k)~=0
            g(k)=imag(V(k)*(conj(yv2))); %to get the imaginary value
            S(k)=P(k)+1i*g(k); %to calculate the apparent power
        else S(k)=P(k)+1i*Q(k);
        end
        V(k)=(1/Y(k,k))*((conj(S(k))/conj(V(k)))-yv1); %to get the value of
node voltages
        ang1(k)=angle(V(k));    %to get the angles
        ang2(k)=rad2deg(ang1(k)); %to convert the radian values to degrees
        if Pg(k)~=0
            V(k)=V0(k)*exp(1i*ang1(k));
        end
    end
        V1=abs(V);
         ang2=rad2deg(ang1);
    E=abs((V-z)/V);
    if E<=10e-4
        break;   %to break the for loop
    end
    Vlt_1(w)=V1(1);
    Vlt_2(w)=V1(2);
    Vlt_3(w)=V1(3);
    ang_1(w)=ang2(1);
    ang_2(w)=ang2(2);
    ang_3(w)=ang2(3);
end

% to show the value column wise
Vlt_1=Vlt_1';
ang_1=ang_1';
Vlt_2=Vlt_2';
ang_2=ang_2';
Vlt_3=Vlt_3';
ang_3=ang_3';
iteration=(1:w-1)';

% to show the values in a table
table(iteration,Vlt_1,ang_1,Vlt_2,ang_2,Vlt_3,ang_3)
```

Output

Z matrix is

0.0000 + 1.0000i	0.0500 + 0.2500i	0.0400 + 0.0200i
0.0500 + 0.2500i	0.0000 + 1.0000i	0.0300 + 0.1500i
0.0400 + 0.0200i	0.0300 + 0.1500i	Inf + 0.0000i

y =

0.0000 - 1.0000i   0.7692 - 3.8462i   20.0000 -10.0000i

```
  0.7692 - 3.8462i   0.0000 - 1.0000i   1.2821 - 6.4103i
 20.0000 -10.0000i   1.2821 - 6.4103i   0.0000 + 0.0000i


p =
 20.7692 -14.8462i
  2.0513 -11.2564i
 21.2821 -16.4103i


Y- bus matrix is
 20.7692 -14.8462i  -0.7692 + 3.8462i -20.0000 +10.0000i
 -0.7692 + 3.8462i   2.0513 -11.2564i  -1.2821 + 6.4103i
-20.0000 +10.0000i  -1.2821 + 6.4103i  21.2821 -16.4103i


ans =
  3×7 table
    iteration    Vlt_1    ang_1    Vlt_2    ang_2      Vlt_3      ang_3
    _________    _____    _____    _____    ______    _______    _______
        1        1.03       0      1.02     1.7965    0.98557    0.48806
        2        1.03       0      1.02     2.2139    0.98602    0.54621
        3        1.03       0      1.02     2.3017    0.98628    0.56041
```

5.10 Discussion & Conclusion

In this experiment, we designed an algorithm, flow chart, and programmed a generalized code for load flow study of a given power system. The sinusoidal steady state of the entire system is provided by the load flow.

It is critical for evaluating the best operating of the existing system and planning future system expansion. It aids in the design of a new power system network, the reduction of system loss, and the selection of transformer taps for efficient operation.

The Gauss-Seidel method is utilized for doing load flow analysis because of these consequences. Though this method takes longer to converge than others, its advantage is its simplicity and ease of performance.

The only adjustment to the code we may need is changing the directory of the file to work with and the given data saved inside the file. The bus numbers and the resistance and reactance values must also be given in the order defined for the code to work and give accurate result.