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Lab Manual:

Power System Simulation Laboratory (AEEB30)

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Contents

INTRODUCTION

Introduction

This course is intended to enhance the learning experience of the student in topics encountered in Engineering.In this lab, students are expected to develop the practical skills required to do the experiments and gain experience in using the basic measuring devices used in Electrical Engineering. Students also learn to interpret the experimental results in terms of the concepts introduced in the Electrical Engineering course.How the student performs in the lab depends on his/her preparation and participation. Each student must participate in all aspectsof the lab to ensure a thorough understanding of the equipment and concepts. The student, Faculty teachingthe lab course, Laboratory In-charge and faculty coordinator all have certain responsibilities towards successful completion of the lab's goals and objectives.

Student Responsibilities

The student is expected tocome prepared for each lab.Lab preparation includes understanding the labexperiment from the lab manual and reading the related textbook material.

Students have to write the allotted experiment for that particular week in the work sheets given and carry them to the Lab. In case of any questions or problems with the preparation, students can contact the Faculty Teaching the Lab course, but in a timely manner.

Students have to be in formal dress code, wear shoes and lab coat for the Laboratory Class.

After the demonstration of experiment by the faculty, student has to perform the experiment individually. They have to note down the observations in the observation Tables drawn in work sheets, do the calculations and analyze the results.

Active participation by each student in lab activities is expected. The student is expected to ask the Faculty any questions they may have related to the experiment.

The student should remain alert and use commonsense while performing the lab experiment.They are also responsible for keeping a professional and accurate record of the labexperiments in the files provided.

Responsibilities of Faculty Teaching the Lab Course

The Faculty shall be completely familiar with each labprior to the laboratory. He/She shall provide the students with details regarding the syllabus and safety review during the first week.Lab experiments should be checked in advance to make sure that everything is in working order.The Faculty should demonstrate and explain the experiment and answer any questions posed by the students.Faculty have to supervise the students while they perform the lab experiments. The Faculty is expected to evaluate the lab worksheets and grade them based on their practical skills and understanding of the experiment by taking Viva Voce. Evaluation of work sheets has to be done in a fair and timely manner to enable the students, for uploading them online through their CMS login within the stipulated time.

Laboratory In-charge Responsibilities

The Laboratory In-charge should ensure that the laboratory is properly equipped, i.e., the Faculty teaching the lab receive any equipment/components necessary to perform the experiments.He/She is responsible for ensuring that all the necessary equipment for the lab is available and in working condition. The Laboratory In-charge is responsible for resolving any problems that are identified by the teaching Faculty or the students.

Course Coordinator Responsibilities

The course coordinator is responsible fo rmaking any necessary corrections in Course Description and lab manual. He/She has to ensure that it is continually updated and available to the students in the CMS learning Portal.

Lab Policy and Grading

The student should understand the following policy:

ATTENDANCE: Attendance is mandatory as per the academic regulations.

LAB RECORD's: The student must:

1. Write the work sheets for the allotted experiment and keep them ready before the beginning of eachlab.
2. Keep all work in preparation of and obtained during lab.
3. Perform the experiment and record the observations in the worksheets.
4. Analyze the resultsand get the work sheets evaluated by the Faculty.
5. Upload the evaluated reports online from CMS LOGIN within the stipulated time.

Grading Policy:

The final grade of this course is awarded using the criterion detailed in the academic regulations. A large portion of the student's grade is determined in the comprehensive final exam of the Laboratory course (SEE PRACTICALS),resulting in a requirement of understanding the concepts and procedure of each lab experiment for successful completion of the lab course.

Pre-Requistes and Co-Requisties:

The lab course is to be taken during the samesemester as AHSC03, but receives a separate grade. Students are required to have completed both AHSC03 and AHSC05 with minimum passing grade or better grade in each.

Course Goals and Objectives

The Physics Laboratory course is designed as a foundation course to provide the student with the knowledge to understand the basic concepts in Physics which have lot of applications in the field of Engineering.

The experiments are designed to complement the concepts introduced in AHSC03. In addition, the student should learn how to record experimental results effectively and present these results in a written report.

More explicitly, the class objectives are:

1. To gain proficiency in the use of common measuring instruments.
2. To enhance understanding of theoretical concepts including:
   - Carrier concentration in semiconducting materials
   - Waves in one Dimension
   - Magnetic Induction
   - Hysteresis losses.
   - Energy Gap in a semiconductor.
   - Photo Diode and its working Principle
   - Numerical Aperture and Acceptance angle of an Optical Fiber.
   - Diffraction due to N Slits
   - Planck's constant
   - Light Emitting Diode and its Working Principle
   - Interference in thin Films
   - Diffraction due to Single slit
3. To develop communication skills through:
   - Verbal interchanges with the Faculty and other students.
   - Preparation of succinct but complete laboratory reports.
   - Maintenance of laboratory worksheets aspermanent, written descriptions of procedures, analysis and results.
4. To compare theoretical predictions with experimental results and to determine the source of any apparent errors.

Use of Laboratory Instruments

One of the major goals of this lab is to familiarize the student with the proper equipment andtechniques for conducting experiments. Some understanding of the lab instruments is necessaryto avoid personal or equipment damage.By understanding the device's purpose and following a fewsimple rules, costly mistakes can be avoided.

The following rules provide a guideline for instrument protection.

Instrument Protection Rules

Data Recording and Reports

The Laboratory Worksheets

The Laboratory Files/Reports

LAB-1 ORIENTATION

1.1 Introduction

In the first experiment period, the students should become familiar with the location of equipment and components in the lab, the course requirements, and the teaching instructor.

1.2 Objective

To familiarize the students with the lab facilities, equipment, standard operating procedures, lab safety, and the course requirements.

1.3 Prelab Preparation:

Read the introduction and procedure of the experiment of respective experiments which are given this manual.

1.4 Equipment needed

Lab manual

1.5 Procedure

1. During the first laboratory period, the faculty coordinator will provide the students with a general idea of what is expected from them in this course. Each student will receive a copy of the syllabus, stating the faculty coordinator's contact information. In addition, the faculty coordinator will review the safety concepts of the course.

2. During this period, the faculty coordinator will briefly review the equipment which will be used throughout the semester. The location of instruments, equipment, and components will be indicated. The guidelines for instrument use will be reviewed.

1.6 Further Probing Experiments

Questions pertaining to this lab must be answered at the end of laboratory report.

LAB-2 FORMATION OF BUS ADMITTANCE AND IMPEDANCE MATRICES

2.1 Introduction

This experiment focuses on the formormation bus admittance matrices by adding one element at a time using MATLAB. In a power system, power is injected into a bus from generators, while the loads are tapped from it. There may be some buses with only generators and there may be other only with loads. Some buses have generators and loads while some other may have static capacitors for reactive power compensation. The surplus power at some of the buses is transported through transmission lines to the bus deficient in power.

2.2 Objective

By the end of this experiment, the student should be able to form bus admittance matrices and impedance by adding one element at a time using MATLAB.

2.3 Prelab Preparation:

Read the material in the textbook that describes bus admittance and impedance matrices . Prior to coming to the lab, complete the Procedure.

2.4 Equipment needed

MATLAB Software

2.5 Background

The equivalent circuit of 4-bus system is shown in the figure below. All the sources of the bus system connected to the common reference at ground potential and the shunt admittance at the busses have been lumped. Besides the ground node, it has four other nodes or buses at which the current from the source is injected into the network.Form the Ybus matrix for the given power system. Write and execute a MATLAB program and also verify the output with the manual calculation results.

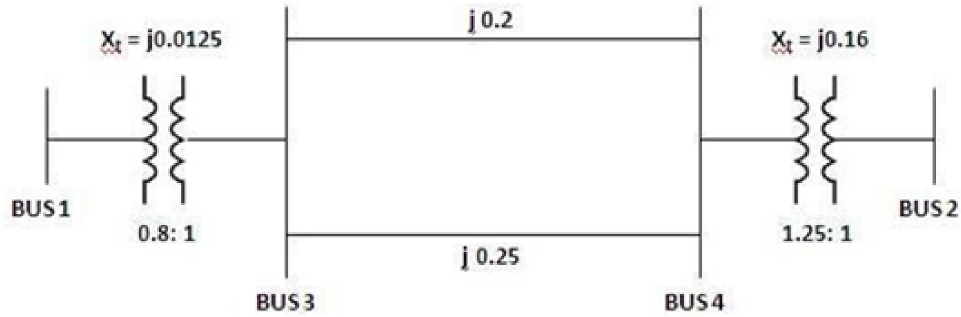

Figure 2.1: Bus system.

2.6 Procedure

1. Read all the data namely R and X for the system.
2. Calculate the mutual or transfer reactance for the reactance between i and j and i=j= 1, 2, 3,4
3. Calculate the self- admittance or point admittance bus i=1, 2, 3, 4. . .
4. Output the Y-bus matrix.
5. Print the result

2.7 Program

```
%%%% bus admittance matrices %%%%%
clear all; clc;
n= input('Enter the number of buses');
fprintf('Enter your choice');
p= input ('1. impedance, 2. admittance');
 if (p==1)
for q= 1:n
for r=q+1:n
fprintf('Enter the impedance value between %d-%d',q,r);
z(q,r)=input(':');
if (z(q,r)==0)
y(q,r)=0;
 else
y(q,r)=inv(z(q,r));
end
y(r,q)= y(q,r);
fprintf('enter the half line charging admittance');
 x(q,r)= input(':');
x(r,q)=x(q,r);
end
end
elseif (p==2)
for a= 1:n
```

```
for b=a+1:n
fprintf('Enter the admittance value between %d-%d',a,b);
y(a,b)=input(':');
y(b,a)= y(a,b);
fprintf('enter the half line charging admittance');
x(a,b)= input(':');
x(b,a)=x(a,b); end
end else
fprintf('enter the correct choice');
end
tr=zeros(n,n);
fprintf('Off-Nominal Tap ratio exists in the system? Enter 1.Yes 2.No');
o= input(':');
if(o==1)
for k=1:n
for l=k+1:n
fprintf('Transformer tap for %d-%d exists? 1.Yes 2.No',k,l)
 g=input(':');
if(g==1)
fprintf('Enter the choice 1.1:a 2.a:1   ?') d=input(':');
fprintf('Enter the tap ratio value(a) between %d-%d',k,l); t(k,l)=input(':');
if (t(k,l)==0)
tr(k,k)=0;
tr(k,l)=0;
 else
yse=y(k,l)/t(k,l);
ysh1=((1-t(k,l))/(t(k,l)^2))*y(k,l);
ysh2=((t(k,l)-1)/t(k,l))*y(k,l);
end
if (d == 1) tr(k,k)=yse+ysh2;
tr(l,l)=yse+ysh1;
 tr(k,l)=yse;
tr(l,k)=tr(k,l);
else tr(k,k)=yse+ysh1;
tr(l,l)=yse+ysh2;
tr(k,l)=yse;
 tr(l,k)=tr(k,l);
end
y(k,l)=0; y(l,k)=y(k,l); end
end end end
for s=1:n
fprintf('enter the self admittance of the bus %d',s);
u(s)=input(':');
end ybus=zeros(n,n);
 for a = 1:n
for b=1:n if (a==b)
for c = 1:n
ybus(a,a)= ybus(a,a)+ y(a,c)+x(a,c);
end
else
ybus(a,b)=-y(b,a);
```

```
end
end ybus(a,a)=ybus(a,a)+u(a);
end
for r=1:n for h = 1:n if(r==h)
ybus(r,r)=ybus(r,r)+tr(r,r);
else
ybus(r,h)=-(y(r,h)+tr(r,h));
end
end
end
ybus
```

%%%%% bus impedance matrices %%%%%

```
clc;
clear all;
e = input('enter the no of elements:'); disp('1.Btwn a new node and reference');
zt=complex(0,0); for i=1:e if(i==1)
a=0;
else [a,c]=size(zb); end
b=a+1;
disp(['elements no:',num2str(i)]); ty(i)=input('enter the type of element:'); z(
zb(b,b)=z(i); for j=1:a zb(j,b)=0;
zb(b,j)=0; end disp(zb);
elseif(ty(i)==2)
zb(b,b)=z(i)+zb(t(i),t(i));
for j=1:a
zb(b,j)=zb(t(i),j);
zb(j,b)=zb(j,t(i)); end
disp(zb); elseif(ty(i)==3)
zb(b,b)=z(i)+zb(s(i),s(i)); for j=1:a zb(b,j)=zb(s(i),j);
zb(j,b)=zb(j,s(i)); end
w=zb(b,b); for j=1:a for k=1:a
zt(j,k)=complex(0,0); zt(j,k)=zb(j,k)-(zb(j,b)*zb(b,k))/w; end
end zb=zt; disp(zb);
elseif(ty(i)==4)
zb(b,b)=z(i)+zb(s(i),s(i))+zb(t(i),t(i))-2*zb(s(i),t(i)); for j=1:a
zb(j,b)=zb(j,s(i))-zb(j,t(i));
zb(b,j)=zb(s(i),j)-zb(t(i),j); end
w=zb(b,b); for j=1:a for k=1:a
zt(j,k)=complex(0,0); zt(j,k)=zb(j,k)-(zb(j,b)*zb(b,k))/w; end
end zb=zt; else
disp('wrong data'); end
end
disp('bus impedance matrix'); disp(zb);
```

2.8 Result

2.9 VIVA Questions

1. What are the elements of Y bus matrix?
2. What is Y bus in power system?
3. What is singular transformation method?
4. What is load flow solution?
5. What is generator bus?
6. Why load flow analysis is done?

2.10 Further Probing Experiments

LAB-3 LOAD FLOW SOLUTION USING GAUSS SEIDEL METHOD

3.1 Introduction

In the Gauss method, we assume the voltage for all the buses except the slack bus where the voltage magnitude and phase angle are specified and remain fixed. Write the text here

3.2 Objective

Find load flow studies without and with generator buses using Gauss Seidel Method.

3.3 Prelab Preparation:

Read the material in the textbook that describes Gauss Seidel Method . Prior to coming to the lab, complete the Procedure.

3.4 Equipment needed

MATLAB Software

3.5 Circuit Diagram

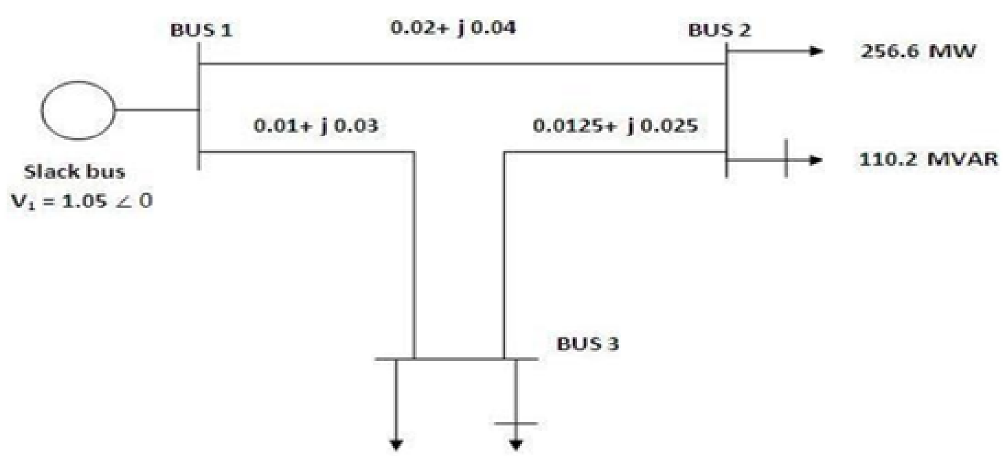

Figure 3.1: The bus system.

3.6 Procedure

STEP1: The slack bus voltage magnitude and angle are measured usually V1 =1 p.u.
load profile known at each bus, we allocate Pi and Qi to all generating Stations

STEP2: Assembly of bus admittance matrix: with the line and shunt admittance dat

3.7 Program

```
%——— FORMATION OF YBUS ———%

clear all; clc;
n= input('Enter the number of buses '); fprintf('Enter your choice');
p= input ('1. impedance, 2. admittance'); if (p==1)
for q= 1:n for r=q+1:n
fprintf('Enter the impedance value between %d-%d',q,r); z(q,r)=input(':');
if (z(q,r)==0)
y(q,r)=0; else
y(q,r)=inv(z(q,r)); end
y(r,q)= y(q,r);
end end
elseif (p==2) for a= 1:n for b=a+1:n
fprintf('Enter the admittance value between %d-%d',a,b); y(a,b)=input(':');
y(b,a)= y(a,b); end
end else
fprintf('enter the correct choice'); end
ybus=zeros(n,n); for a = 1:n
for b=1:n if (a==b) for c = 1:n
ybus(a,a)= ybus(a,a)+ y(a,c); end
else
ybus(a,b)=-y(b,a); end
end end ybus

%——— BUSDATA ———%

busdata =input(' Bus number | 1.Slack 2.PQ 3.PV | V| angle|Pg | Qg | PL
| QL     | Qmin | Qmax '); bus = busdata(:,1); type = busdata(:,2);
V = busdata(:,3);
th = busdata(:,4); GenMW = busdata(:,5); GenMVAR = busdata(:,6); LoadMW = busdat
LoadMVAR = busdata(:,8); Qmin = busdata(:,9); Qmax = busdata(:,10); nbus = max(b
P = GenMW - LoadMW;
Q = GenMVAR - LoadMVAR;
Vprev = V; toler = 1;
iteration = 1;
```

```
disp(' Bus number | 1.Slack 2.PQ 3.PV | V| angle|Pg | Qg | PL | QL | Qmin | Qmax
busdata ybus


 %——— VOLTAGE CALCULATION ———%


while (toler> 0.00001) for i = 2:nbus
sumyv = 0;
for k = 1:nbus if i ~= k
sumyv = sumyv + ybus(i,k)* V(k); end
end
if type(i) == 2
Q(i) = -imag(conj(V(i))*(sumyv + ybus(i,i)*V(i)));
if (Q(i) >Qmax(i)) || (Q(i) <Qmin(i)) if Q(i) <Qmin(i)
Q(i) = Qmin(i); else
Q(i) = Qmax(i); end
type(i) = 3; end
end
V(i) = (1/ybus(i,i))*((P(i)-j*Q(i))/conj(V(i)) - sumyv); if type(i) == 2
V(i) = pol2rect(abs(Vprev(i)), angle(V(i))); end
end
iteration = iteration + 1;
toler = max(abs(abs(V) - abs(Vprev))); Vprev = V;
end iteration V
Vmag = abs(V)
Ang = 180/pi*angle(V) sum=0;


 %——— REAL AND REACTIVE POWER CALCULATION ———%


for i=1:nbus if i==1
for f=1:nbus sum=sum+(ybus(i,f)*V(f)); real_power(i)=(real(V(i)*sum))*100;
reactive_power(i)=-(imag(V(i)*sum))*100; end
else end end
real_power reactive_power
```

3.8 Further Probing Experiments

LAB-4 LOAD FLOW SOLUTION USING NEWTON RAPHSON AND FDLF METHOD

4.1 Introduction

Newton Raphson Method is an iterative technique for solving a set of various nonlinear equations with an equal number of unknowns. There are two methods of solutions for the load flow using Newton Raphson Method.The fast decoupled power flow method is a very fast and efficient method of obtaining power flow problem solution. In this method, both, the speeds as well as the sparsity are exploited. As we know, the sparsity feature of admittance matrix minimizes the computer memory requirements and results in faster computations.

4.2 Objective

Develop in MATLAB to find load flow studies using Newton Raphson and Fast Decoupled load Flow (FDLF) method.

4.3 Prelab Preparation:

Read the material in the textbook that describes Newton Raphson and Fast Decoupled load Flow (FDLF) method . Prior to coming to the lab, complete the Procedure.

4.4 Equipment needed

MATLAB Software

4.5 Procedure

```
%%% Newton Raphson Method%%%
clear all; clc;
v=[1.05;1.0;1.04]; d=[0;0;0];
ps=[-4;2.0]; qs=-2.5;
n= input('Enter the number of buses '); fprintf('Enter your choice');
p= input ('1. impedance, 2. admittance'); if (p==1)
for q= 1:n
for r=q+1:n
fprintf('Enter the impedance value between %d-%d',q,r); z(q,r)=input(':');
if (z(q,r)==0)
y(q,r)=0; else
y(q,r)=inv(z(q,r)); end
y(r,q)= y(q,r); end
```

```
end
elseif (p==2) for a= 1:n for b=a+1:n
fprintf('Enter the admittance value between %d-%d',a,b); y(a,b)=input(':');
y(b,a)= y(a,b); end
end else
fprintf('enter the correct choice'); end
ybus=zeros(n,n); for a = 1:n
for b=1:n if (a==b) for c = 1:n
ybus(a,a)= ybus(a,a)+ y(a,c); end
else
ybus(a,b)=-y(b,a); end
end end ybus
y=abs(ybus); t=angle(ybus); iter=0;
pwracur=0.00025;% Power accuracy
dc=10;% Set the maximum power residual to a high value while max(abs(dc))>pwracu
iter=iter+1 p=[v(2)*v(1)*y(2,1)*cos(t(2,1)-
d(2)+d(1))+v(2)^2*y(2,2)*cos(t(2,2))+v(2)*v(3)*y(2,3)*cos(t(2,3)- d(2)+d(3));
v(3)*v(1)*y(3,1)*cos(t(3,1)- d(3)+d(1))+v(3)^2*y(3,3)*cos(t(3,3))+v(3)*v(2)*y(3,
q=-v(2)*v(1)*y(2,1)*sin(t(2,1)-d(2)+d(1))-v(2)^2*y(2,2)*sin(t(2,2))- v(2)*v(3)*y
j(1,1)=v(2)*v(1)*y(2,1)*sin(t(2,1)- d(2)+d(1))+v(2)*v(3)*y(2,3)*sin(t(2,3)-d(2)+
j(1,2)=-v(2)*v(3)*y(2,3)*sin(t(2,3)-d(2)+d(3)); j(1,3)=v(1)*y(2,1)*cos(t(2,1)- d
j(2,1)=-v(3)*v(2)*y(3,2)*sin(t(3,2)-d(3)+d(2));
j(2,2)=v(3)*v(1)*y(3,1)*sin(t(3,2)- d(3)+d(1))+v(3)*v(2)*y(3,2)*sin(t(3,2)-d(3)+
j(2,3)=v(3)*y(2,3)*cos(t(3,2)-d(3)+d(2));
j(3,1)=v(2)*v(1)*y(2,1)*cos(t(2,1)- d(2)+d(1))+v(2)*v(3)*y(2,3)*cos(t(2,3)-d(2)+
j(3,2)=-v(2)*v(3)*y(2,3)*cos(t(3,2)-d(2)+d(3));
j(3,3)=-v(1)*y(2,1)*sin(t(2,1)-d(2)+d(1))-2*v(2)*y(2,2)*sin(t(2,2))- v(3)*y(2,3)
dp=ps-p; dq=qs-q; dc=[dp;dq] j
dx=j\dc d(2)=d(2)+dx(1);
d(3)=d(3)+dx(2);
v(2)=v(2)+dx(3);
v,d,delta=180/pi*d; end
p1=v(1)^2*y(1,1)*cos(t(1,1))+v(1)*v(2)*y(1,2)*cos(t(1,2)-
d(1)+d(2))+v(1)*v(3)*y(1,3)*cos(t(1,3)-d(1)+d(3));
q1=-v(1)^2*y(1,1)*sin(t(1,1))-v(1)*v(2)*y(1,2)*sin(t(1,2)-d(1)+d(2))- v(1)*v(3)*
q3=-v(3)*v(1)*y(3,1)*sin(t(3,1)-d(3)+d(1))-v(3)*v(2)*y(3,2)*sin(t(3,2)- d(3)+d(2)

%%% Fast decoupled method%%%
V1= 1.05; V2 = 1.0; V3 = 1.04;
d1 = 0; d2 = 0; d3=0;
Ps2=-4; Ps3 =2.0;
Qs2= -2.5;
YB = [ 20-j*50 -10+j*20 -10+j*30
-10+j*20 26-j*52 -16+j*32
-10+j*30 -16+j*32 26-j*62];
Y = abs(YB); t=angle(YB);
B =[-52 32; 32 -62]
Binv = inv(B)
iter=0;
pwracur = 0.0003; % Power accuracy
DC = 10; % Set the max of power mismatch to a high value
```

```
while max(abs(DC)) > pwracur
iter = iter +1;
P2= V2*V1*Y(2,1)*cos(t(2,1)-d2+d1)+V2^2*Y(2,2)*cos(t(2,2))+ ...
V2*V3*Y(2,3)*cos(t(2,3)-d2+d3);
P3= V3*V1*Y(3,1)*cos(t(3,1)-d3+d1)+V3^2*Y(3,3)*cos(t(3,3))+ ...
V3*V2*Y(3,2)*cos(t(3,2)-d3+d2);
Q2=-V2*V1*Y(2,1)*sin(t(2,1)-d2+d1)-V2^2*Y(2,2)*sin(t(2,2))- ...
V2*V3*Y(2,3)*sin(t(2,3)-d2+d3);
DP2 = Ps2 - P2; DP2V = DP2/V2;
DP3 = Ps3 - P3; DP3V = DP3/V3;
DQ2 = Qs2 - Q2; DQ2V = DQ2/V2;
DC =[DP2; DP3; DQ2];
Dd = -Binv*[DP2V;DP3V];
DV = -1/B(1,1)*DQ2V;
d2 =d2+Dd(1);
d3 =d3+Dd(2);
V2= V2+DV;
angle2 =180/pi*d2;
angle3 =180/pi*d3;
R = [iter d2 d3 V2 DP2 DP3 DQ2];
disp(R)
end
Q3=-V3*V1*Y(3,1)*sin(t(3,1)-d3+d1)-V3^2*Y(3,3)*sin(t(3,3))- ...
V3*V2*Y(3,2)*sin(t(3,2)-d3+d2);
P1= V1^2*Y(1,1)*cos(t(1,1))+V1*V2*Y(1,2)*cos(t(1,2)-d1+d2)+ ...
V1*V3*Y(1,3)*cos(t(1,3)-d1+d3);
Q1=-V1^2*Y(1,1)*sin(t(1,1))-V1*V2*Y(1,2)*sin(t(1,2)-d1+d2)- ...
V1*V3*Y(1,3)*sin(t(1,3)-d1+d3);
S1=P1+j*Q1
Q3
```

4.6 Further Probing Experiments

LAB-5 POWER SYSTEM FAULT ANALYSIS

5.1 Introduction

This experiment focuses on the power system fault analysis.The fault analysis of a power system is required in order to provide information for the selection of switchgear, setting of relays and stability of system operation. A power system is not static but changes during operation (switching on or off of generators and transmission lines) and during planning (addition of generators and transmission lines). Thus fault studies need to be routinely performed by utility engineers (such as in the CEB). Faults usually occur in a power system due to either insulation failure, flashover, physical damage or human error. These faults, may either be three phase in nature involving all three phases in a symmetrical manner, or may be asymmetrical where usually only one or two phases may be involved. Faults may also be caused by either short-circuits to earth or between live conductors, or may be caused by broken conductors in one or more phases. Sometimes simultaneous faults may occur involving both short-circuit and brokenconductor faults (also known as open-circuit faults). Balanced three phase faults may be analysed using an equivalent single phase circuit. With asymmetrical three phase faults, the use of symmetrical components help to reduce the complexity of the calculations as transmission lines and components are by and large symmetrical, although the fault may be asymmetrical. Fault analysis is usually carried out in per-unit quantities (similar to percentage quantities) as they give solutions which are somewhat consistent over different voltage and power ratings, and operate on values of the order of unity

5.2 Objective

By the end of this experiment, the student should be able to analysise power system fault using MATLAB.

5.3 Prelab Preparation:

Read the material in the textbook that describes power system fault analysis . Prior to coming to the lab, complete the Procedure.

5.4 Equipment needed

MATLAB Software

5.5 Background

```
V012 = [0.6 90   1.0 30   0.8  -30];
rankV012=length(V012(1,:));
if rankV012 == 2
```

```
mag= V012(:,1); ang=pi/180*V012(:,2);
V012r=mag.*(cos(ang)+j*sin(ang));
elseif rankV012 ==1
V012r=V012;
Else
fprintf('\n Symmetrical components must be expressed in a one column array in re
fprintf(' or in a two column array in polar form, with 1st column magnitude & 2n
fprintf(' phase angle in degree. \n')
return, end
a=cos(2*pi/3)+j*sin(2*pi/3);
A = [1 1 1; 1 a^2 a; 1 a a^2];
Vabc= A*V012r
Vabcp= [abs(Vabc) 180/pi*angle(Vabc)];
fprintf(' \n Unbalanced phasors \n')
fprintf(' Magnitude Angle Deg.\n')
disp(Vabcp)
Vabc0=V012r(1)*[1; 1; 1];
Vabc1=V012r(2)*[1; a^2; a];
Vabc2=V012r(3)*[1; a; a^2];
```

5.6 Procedure

1. Open Matlab − − − > File − − − > New − − − > Script
2. Write the program
3. Enter F5 to run the program
4. Observe the results in MATLAB command window.

5.7 Result

5.8 VIVA Questions

1. What are the causes of electrical faults?
2. What is unsymmetrical fault?
3. Why is fault current asymmetrical in nature?
4. What are the different faults?
5. How can we prevent electrical faults?
6. What is difference between symmetrical and unsymmetrical fault?

5.9 Further Probing Experiments

LAB-6 TRANSIENT RESPONSE OF RLC CIRCUIT

6.1 Introduction

This experiment focuses on the transient response of RLC circuit. A unit step input will excite this circuit, producing a transient voltage response across all circuit elements. These responses will be analyzed by theory, simulation and experimental results. The primary response properties of concern are initial value and final voltage values along with voltage measurements at intermediate steps.

6.2 Objective

By the end of this experiment, the student should be able to obtain transient response of RLC circuit using PSCAD.

6.3 Prelab Preparation:

Read the material in the textbook that describes transient response of RLC circuit. Prior to coming to the lab, complete the Procedure.

6.4 Equipment needed

PSCAD Software

6.5 Background

A series RLC circuit may be modeled as a second order differential equation. Finding the solution to this second order equation involves finding the roots of its characteristic equation. Knowing the above RLC circuit properties along with initial and final transient values for voltage or current then enables the transient capacitor voltage or transient inductor current to be calculated. This is done using the following equations (where infinity in this case will refer to the value when the circuit reaches steady-state before changing again):

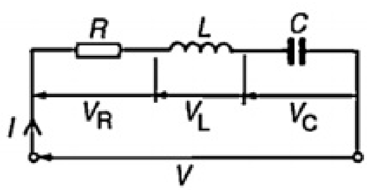

Figure 6.1: RLC circuit.

6.6 Procedure

1. Make the connections as shown in the circuit diagram by using PSCAD master library.
2. Measure readings in each element.
3. Observe the wave forms

6.7 Result

6.8 VIVA Questions

1. What are transients?
2. What are initial and steady state conditions?
3. Define step signal, unit step signal, step voltage and step current.
4. How do resistor, inductor and capacitor behave when step voltage and step current applied to them?
5. Write any three reasons of transients in any circuit. Define time constant.
6. Determine equation for i(t), vR(t) and vL(t) when an R-L series circuit is switched on to a voltage of V volts.

6.9 Further Probing Experiments

Q1. Use MATLAB/Simulink to obtain the transient response of RLC circuitfor the circuit in Part 1. First, enter the circuit shown in Figure 6.1 using down node as the reference or "ground" node. To measure the short-circuit current in a loop, place an ammeter in each loop in series and to measure the voltage across open circuited terminals connect a voltmeter across the open circuited terminals. Record your MATLAB/Simulink file and the data obtained from the simulation in your laboratory notebook by pasting in the printouts.

LAB-6 POINT BY POINT METHOD

7.1 Introduction

Transient stability analysis using the direct method is to identify the mathematical dynamic model of a system, to derive its Lyapunov function, and to evaluate the stability criteria directly from the critical energy.

7.2 Objective

Development of MATLAB program for Transient stability analysis of single machine infinite bus and multi machine system by point by point method.

7.3 Prelab Preparation:

Read the material in the textbook that describes Transient stability analysis. Prior to coming to the lab, complete the Procedure.

7.4 Equipment needed

PSCAD Software

7.5 Program

```
Save this part in another m-file with name swing.m
%Defining the function swing
function[time ang]=swing(tc)
k=0;v=1;E=1.1;pm=0.9;T=0.5;delT=0.05;ddelta=0;time(1)=0;ang(1)=21.64;xdf=1
.25;xaf=0.55;t=0;
delta=21.64*pi/180;i=2;
m=2.52/(180*50);
while t<T
if t<tc
x=xdf;
else x=xaf;
end
pmax=(E*v)/x;

pa=pm-pmax*sin(delta);
ddelta=ddelta+(delT^2*(pa/m));
delta=(delta*180/pi+ddelta)*(pi/180);
deltadeg=delta*180/pi;
```

```
t=t+delT;
time(i)=t;
ang(i)=deltadeg;
i=i+1;
end
end
PROGRAM - 2:
Main program that is dependent on swing.m
%solution of Swing equation by point-by-point method
clc
clear all
close all
for i=1:2
tc=input('enter the value of clearing time:\n');
[time,ang]=swing(tc)
t(:,1)=time;
a(:,i)=ang;
end
plot(t,a(:,1),'*-',t,a(:,2),'d-')
axis([0 0.5 0 inf])
t,a

Inputs to main program:
Enter the value of clearing time as
0.25 sec, and
5 sec
```

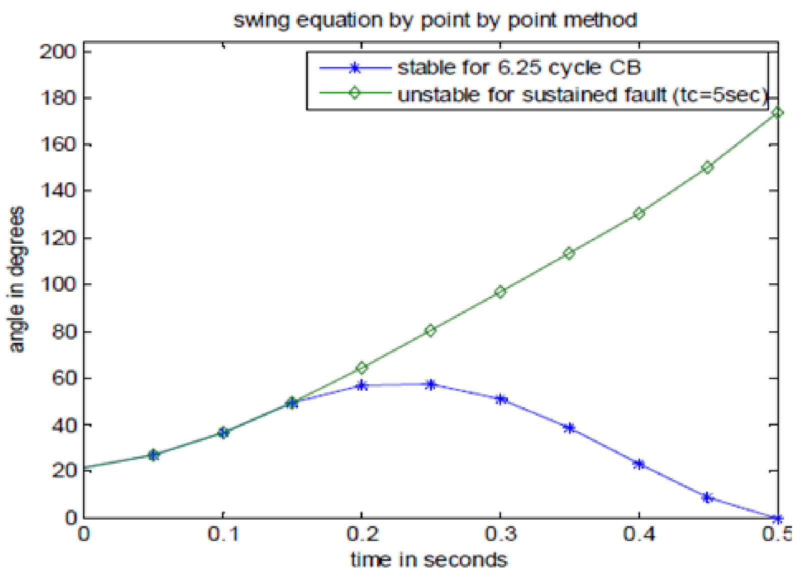

Figure 7.1: Swing equation by point by point method.

7.6 Result

7.7 VIVA Questions

1. What are transients?
2. What are initial and steady state conditions?
3. Define step signal, unit step signal, step voltage and step current.
4. How do resistor, inductor and capacitor behave when step voltage and step current applied to them?
5. Write any three reasons of transients in any circuit. Define time constant.
6. Determine equation for i(t), vR(t) and vL(t) when an R-L series circuit is switched on to a voltage of V volts.

7.8 Further Probing Experiments

LAB-8 THREE PHASE SHORT CIRCUIT ANALYSIS IN A SYNCHRONOUS MACHINE

8.1 Introduction

The transient process of synchronous generator after three-phase short circuit, deduces the expression of stator current in the transient process of synchronous generator, and verifies the theoretical conclusion through simulation. After the short circuit occurs, the electromagnetic transient process is complex.

8.2 Objective

By the end of this experiment, the student should be able to Analyze symmetrical faults and short circuit studies in a given synchronous machine using PSCAD.

8.3 Prelab Preparation:

Read the material in the textbook that describes the parameters of a typical transmission line and modeling it in PSCAD.. Prior to coming to the lab, complete the Procedure.

8.4 Equipment needed

PSCAD Software

8.5 Procedure

1. Make the connections as shown in the circuit diagram by using PSCAD master library.
2. Measure readings in each element.
3. Observe the wave forms

8.6 Further Probing Experiments

8.7 Circuit Diagram

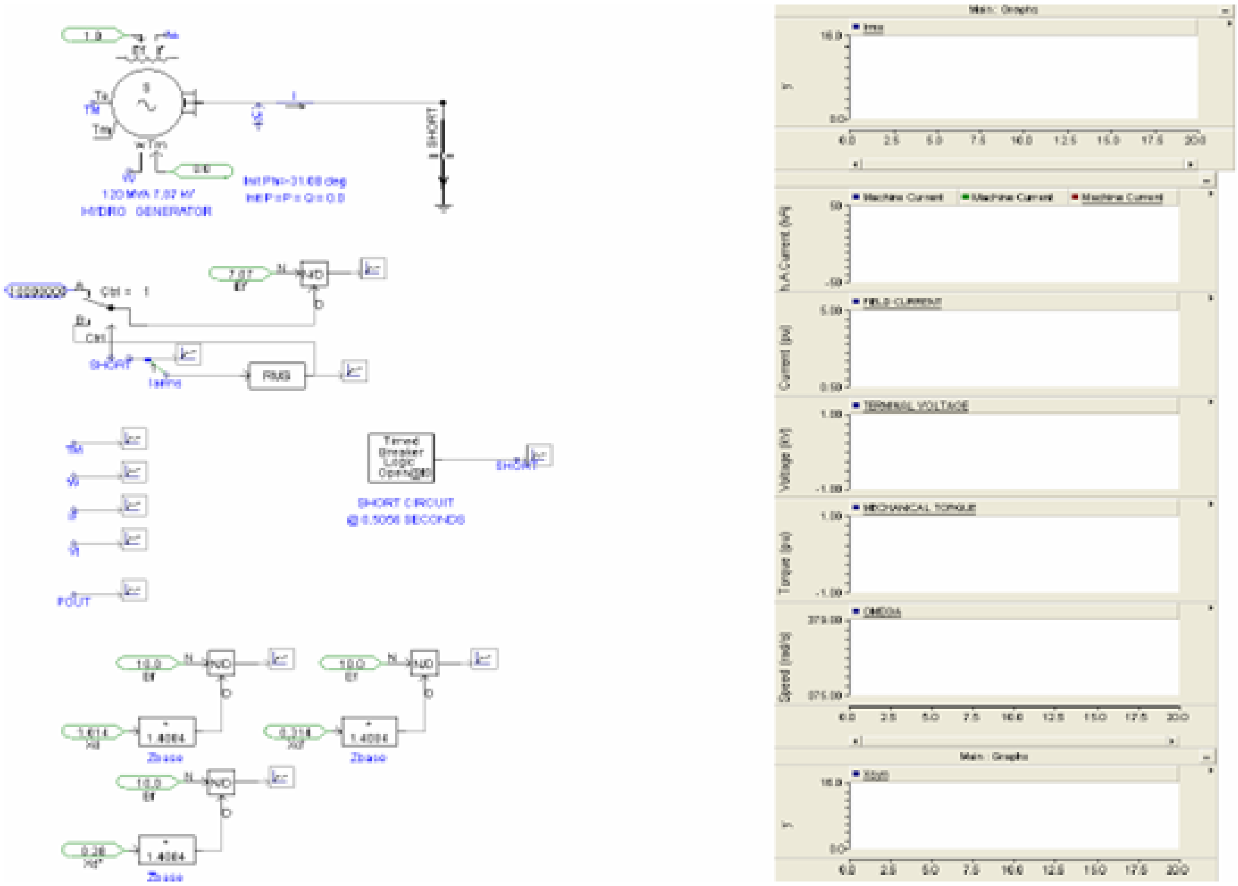

Figure 8.1: RLC circuit.

LAB-9 STUDY OF TRANSMISSION SYSTEM AND SHORT CIRCUIT ANALYSIS OF 9 BUS SYSTEM

9.1 Introduction

It is an essential and compulsory to design an empty interrupted electrical power system network having security, stability and reliability in this electricity dependent era. In this paper Short circuit analysis and Protection relying coordination of IEEE 9-Bus system is analyzed and designing of overcurrent relaying scheme to operate the relay quickly and disconnect the faulty section from healthy section.

9.2 Objective

Study of simple transmission system and also perform short circuit analysis on IEEE 9 bus system using PSCAD.

9.3 Prelab Preparation:

Read the introduction and procedure of the experiment of respective experiments which are given this manual.

9.4 Equipment needed

Lab manual

9.5 Circuit Diagram

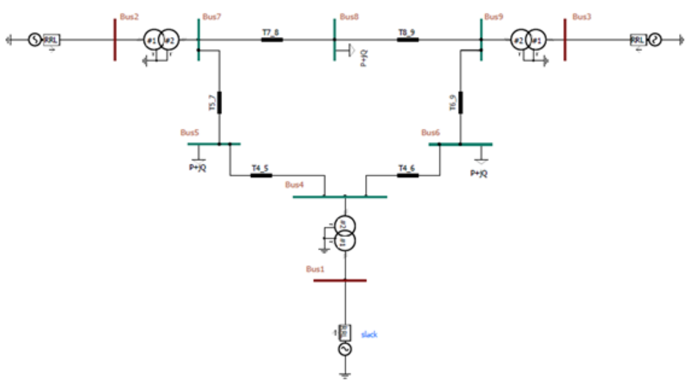

Figure 9.1: IEEE bus system.

9.6 Procedure

1. Make the connections as shown in the circuit diagram by using PSCAD master library.
2. Measure readings in each element.
3. Observe the wave forms

9.7 Further Probing Experiments

LAB-10 TRANSFORMER INRUSH CURRENT

10.1 Introduction

Magnetizing inrush current in transformer is the current which is drown by a transformer at the time of energizing the transformer. This current is transient in nature and exists for few milliseconds. The inrush current may be up to 10 times higher than normal rated current of transformer

10.2 Objective

Determination of transformer inrush current under unbalanced three phase parameters using PSCAD.

10.3 Prelab Preparation:

Read the introduction and procedure of the experiment of respective experiments which are given this manual.

10.4 Equipment needed

Lab manual

10.5 Circuit Diagram

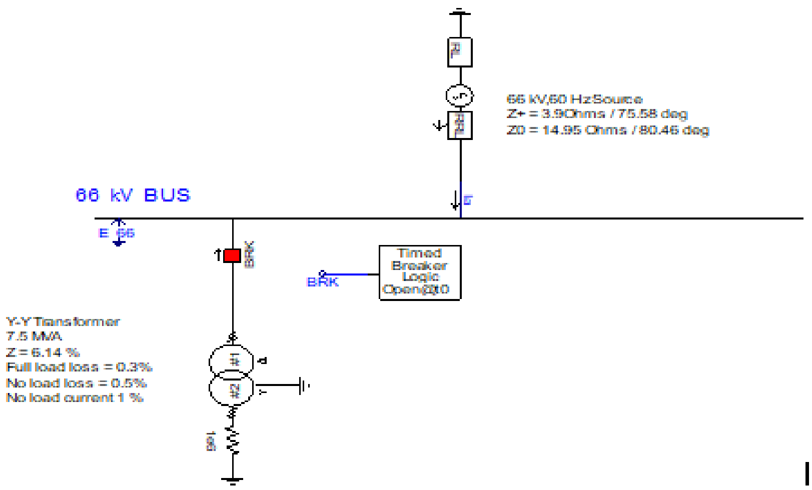

Figure 10.1: Transformer energizing circuit.

10.6 Procedure

1. Make the connections as shown in the circuit diagram by using PSCAD master library.
2. Measure readings in each element.
3. Observe the wave forms

10.7 Further Probing Experiments

LAB-11 SMALL SIGNAL STABILITY ANALYSIS

11.1 Introduction

Small-signal stability analysis is about power system stability when subject to small disturbances. If power system oscillations caused by small disturbances can be suppressed, such that the deviations of system state variables remain small for a long time, the power system is stable.

11.2 Objective

Editing and Building a VI, Creating a VI

11.3 Prelab Preparation:

Read the introduction and procedure of the experiment of respective experiments which are given this manual.

11.4 Equipment needed

Lab manual

11.5 Circuit Diagram

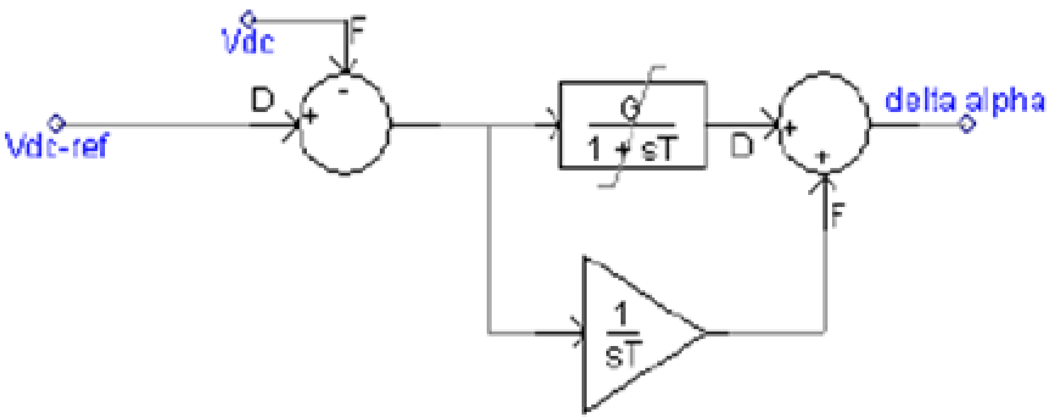

Figure 11.1: The control block for regulation of dc voltage of capacitor

11.6 Procedure

1. Make the connections as shown in the circuit diagram by using PSCAD master library.
2. Measure readings in each element.
3. Observe the wave forms

11.7 Further Probing Experiments

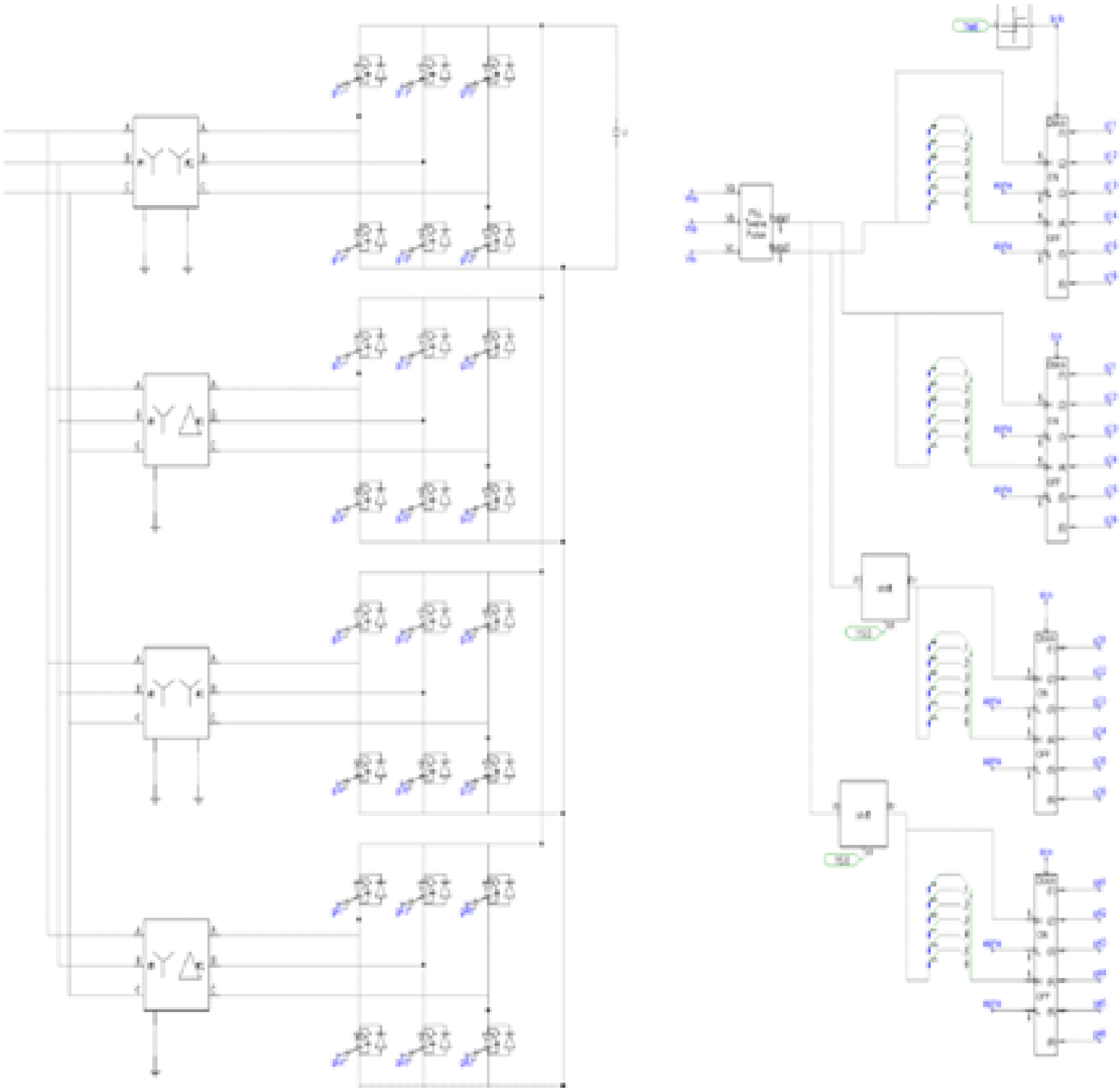

Figure 11.2: Simulation 24-pulse converter in PSCAD/EMTDC program

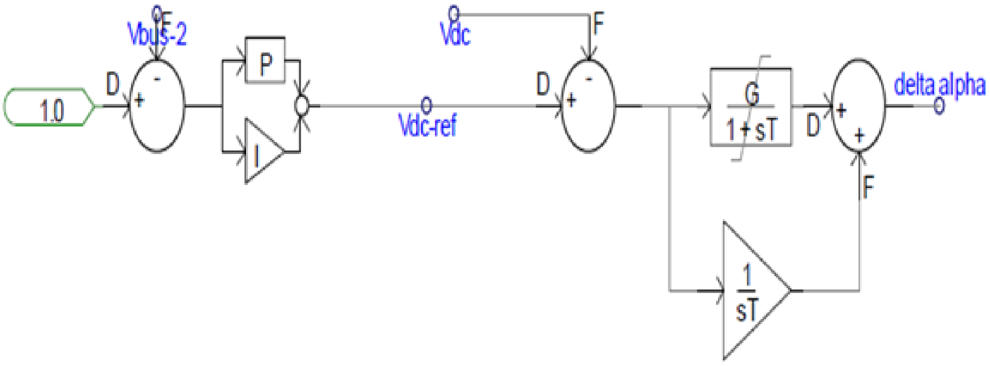

Figure 11.3: The control block of alternative voltage output of STSTCOM

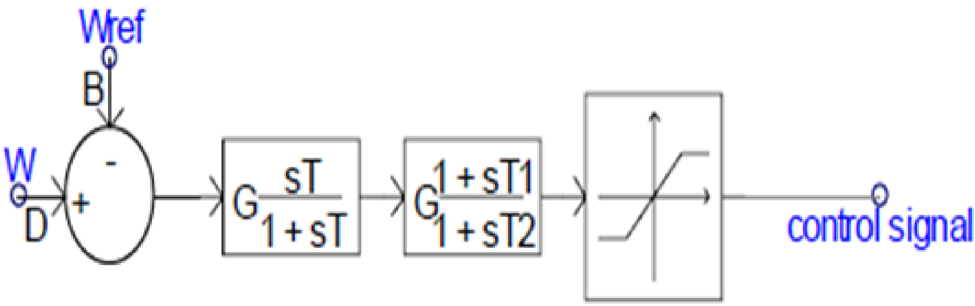

Figure 11.4: Control loop of STSTCOM for damping LFO

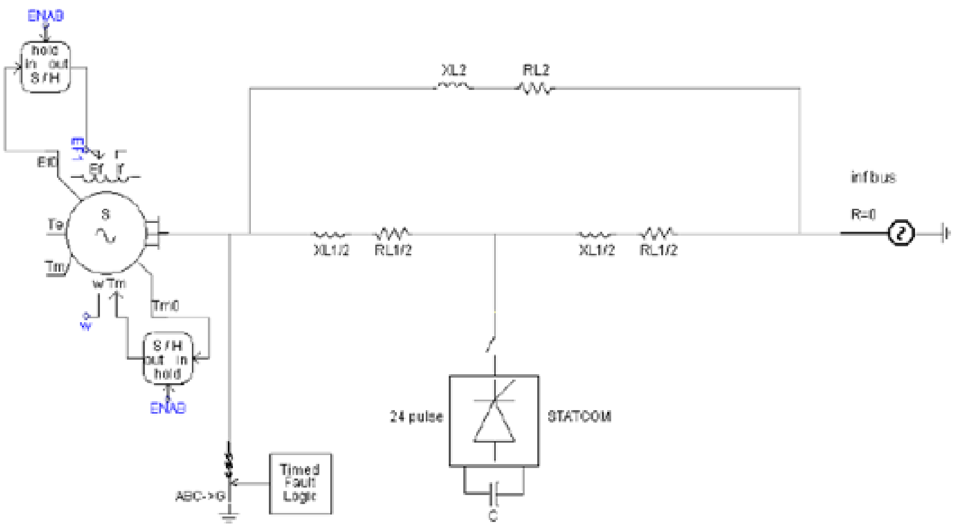

Figure 11.5: Single machine power system interconnected to inf.bus

LAB-12 TRANSMISSION LINE PARAMETERS

12.1 Introduction

The transmission line has mainly four parameters, resistance, inductance, capacitance and shunt conductance. These parameters are uniformly distributed along the line.

12.2 Objective

Obtain parameters of a typical transmission line and modeling it in PSCAD.

12.3 Prelab Preparation:

Read the introduction and procedure of the experiment of respective experiments which are given this manual.

12.4 Equipment needed

Lab manual

12.5 Circuit Diagram

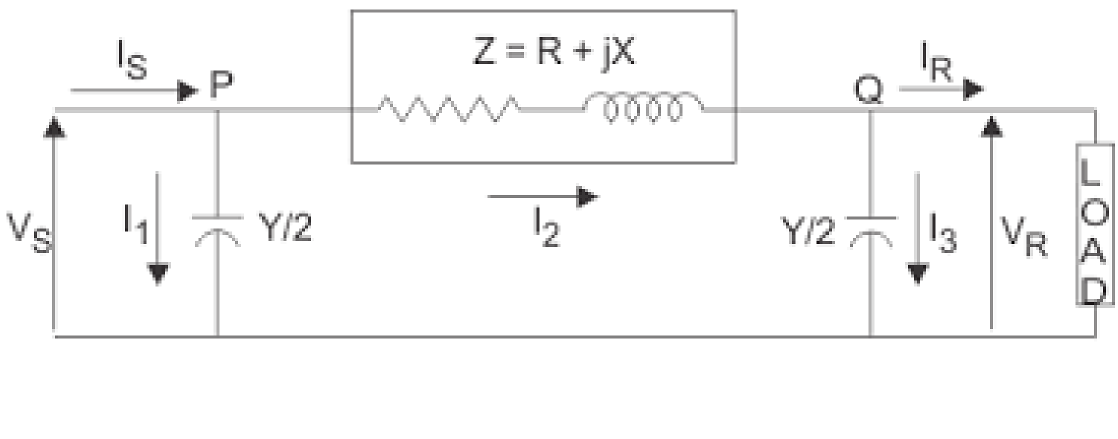

Figure 12.1: Transmission line

12.6 Procedure

1. Make the connections as shown in the circuit diagram by using PSCAD master library.
2. Measure readings in each element.
3. Observe the wave forms

12.7 Further Probing Experiments

LAB-13 LOAD FREQUENCY CONTROL

13.1 Introduction

Load frequency control of an interconnected power system means the interconnection of more than one control area through tie lines. Sudden load variation in any control area of an interconnected power system will lead to both frequency change and tie line power deviation.

13.2 Objective

Obtain the frequency response of single and two area power system using PSCAD

13.3 Prelab Preparation:

Read the introduction and procedure of the experiment of respective experiments which are given this manual.

13.4 Equipment needed

Lab manual

13.5 Circuit Diagram

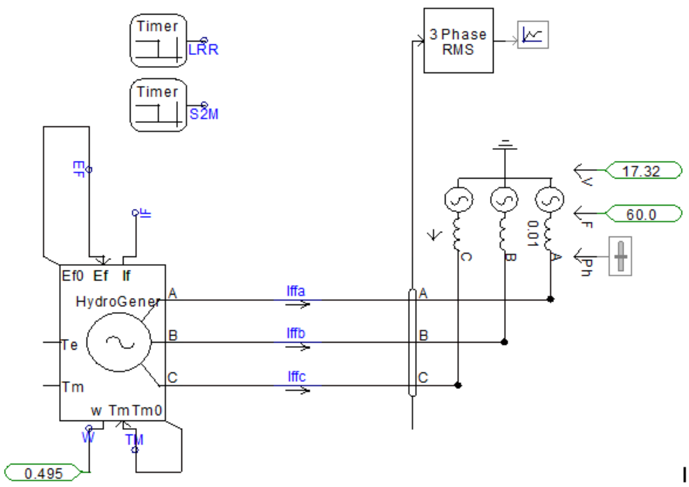

Figure 13.1: FFT and harmonic distortion blocks are taken from CSMF library

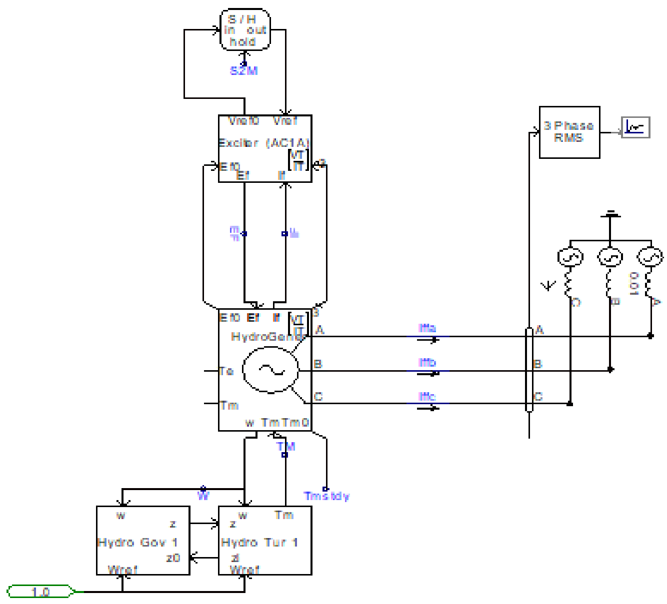

Figure 13.2: Initializing the multi machine to a Load Flow

13.6 Procedure

1. Make the connections as shown in the circuit diagram by using PSCAD master library.
2. Measure readings in each element.
3. Observe the wave forms

13.7 Further Probing Experiments

LAB-14 POWER QUALITY

14.1 Introduction

Power quality refers to the ability of electrical equipment to consume the energy being supplied to it. A number of power quality issues including electrical harmonics, poor power factor, voltage instability and imbalance impact on the efficiency of electrical equipment. Higher energy usage and costs.

14.2 Objective

Familiarization with PSCAD and Understanding of :
a) Reactive power and power factor correction in AC circuits.
b) Current harmonics drawn by power electronics interface

14.3 Prelab Preparation:

Read the introduction and procedure of the experiment of respective experiments which are given this manual.

14.4 Equipment needed

Lab manual

14.5 Circuit Diagram

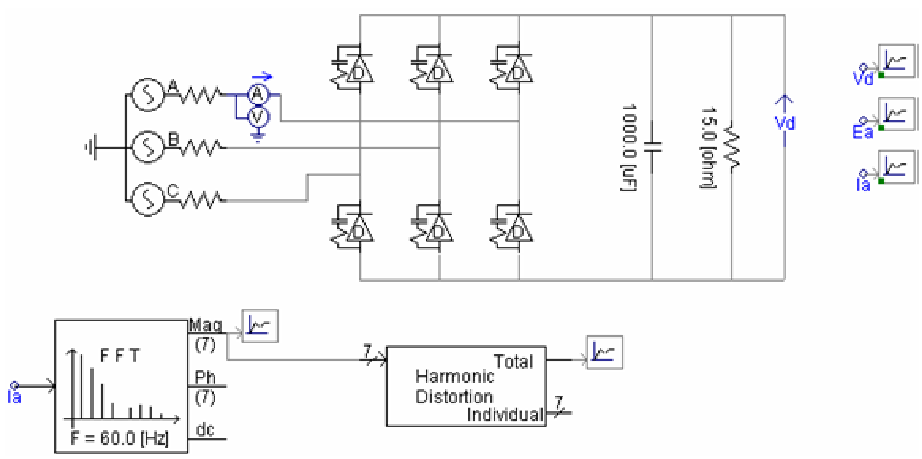

Figure 14.1: FFT and harmonic distortion blocks are taken from CSMF library

14.6 Procedure

1. Make the connections as shown in the circuit diagram by using PSCAD master library.
2. Measure readings in each element.
3. Observe the wave forms

14.7 Further Probing Experiments

LAB-15 DISTANCE PROTECTION

15.1 Introduction

Impedance relays and automatics are devices whose function is based on the magnitude and angle of impedance. The main group of impedance relays is distance protection devices. Other types of impedance relays are e.g. loss of synchronism protection, loss of excitation protection, or impedance automatics like fault locator.

15.2 Objective

Development of PSCAD model to study the distance protection scheme in long transmission line

15.3 Prelab Preparation:

Read the introduction and procedure of the experiment of respective experiments which are given this manual.

15.4 Equipment needed

Lab manual

15.5 Circuit Diagram

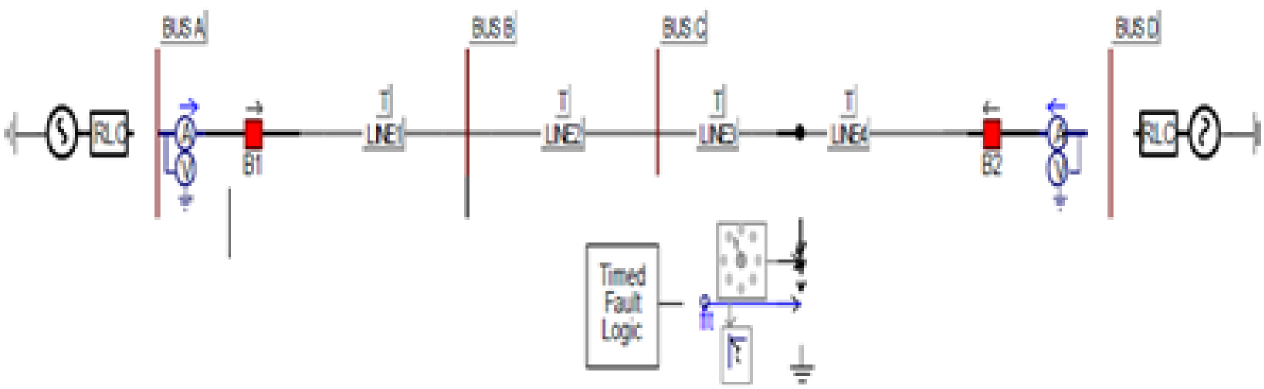

Figure 15.1: Distance protection scheme

15.6 Procedure

1. Make the connections as shown in the circuit diagram by using PSCAD master library.
2. Measure readings in each element.
3. Observe the wave forms

15.7 Further Probing Experiments

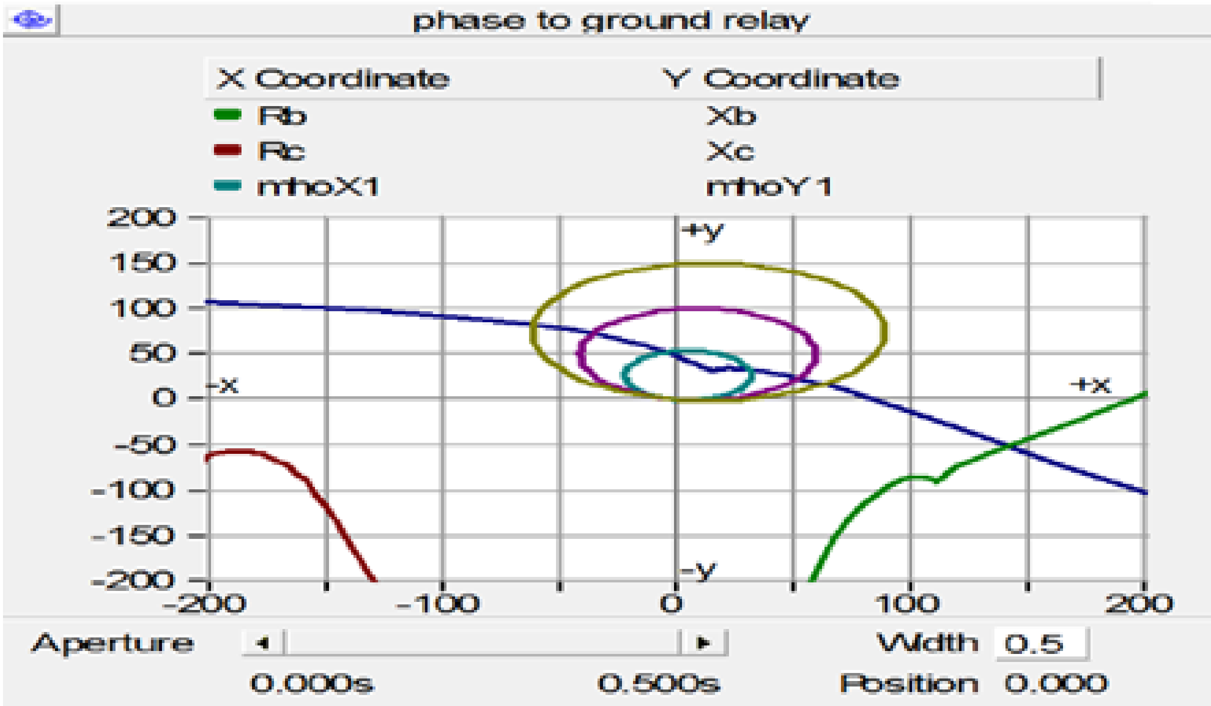

Figure 15.2: Distance protection scheme graph

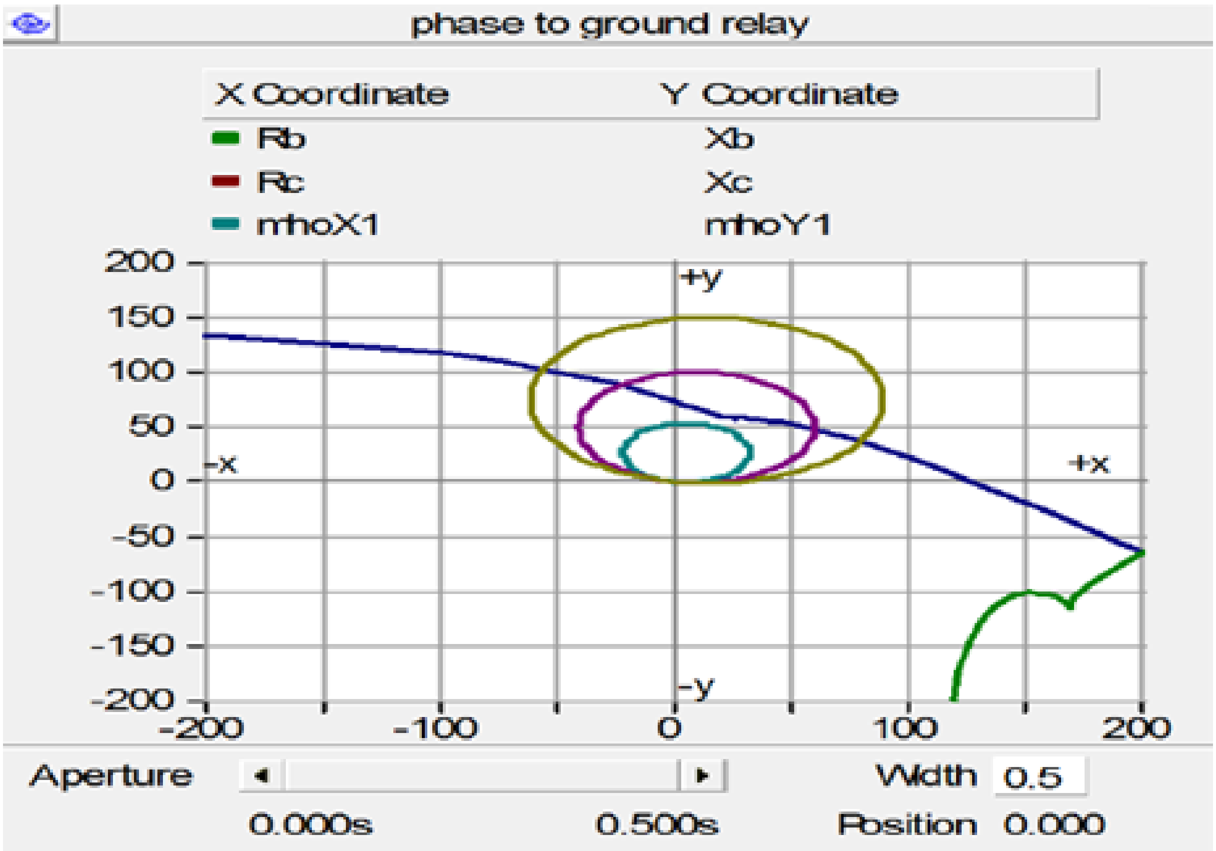

Figure 15.3: Fault at 20 km from Bus-B, Zone 2

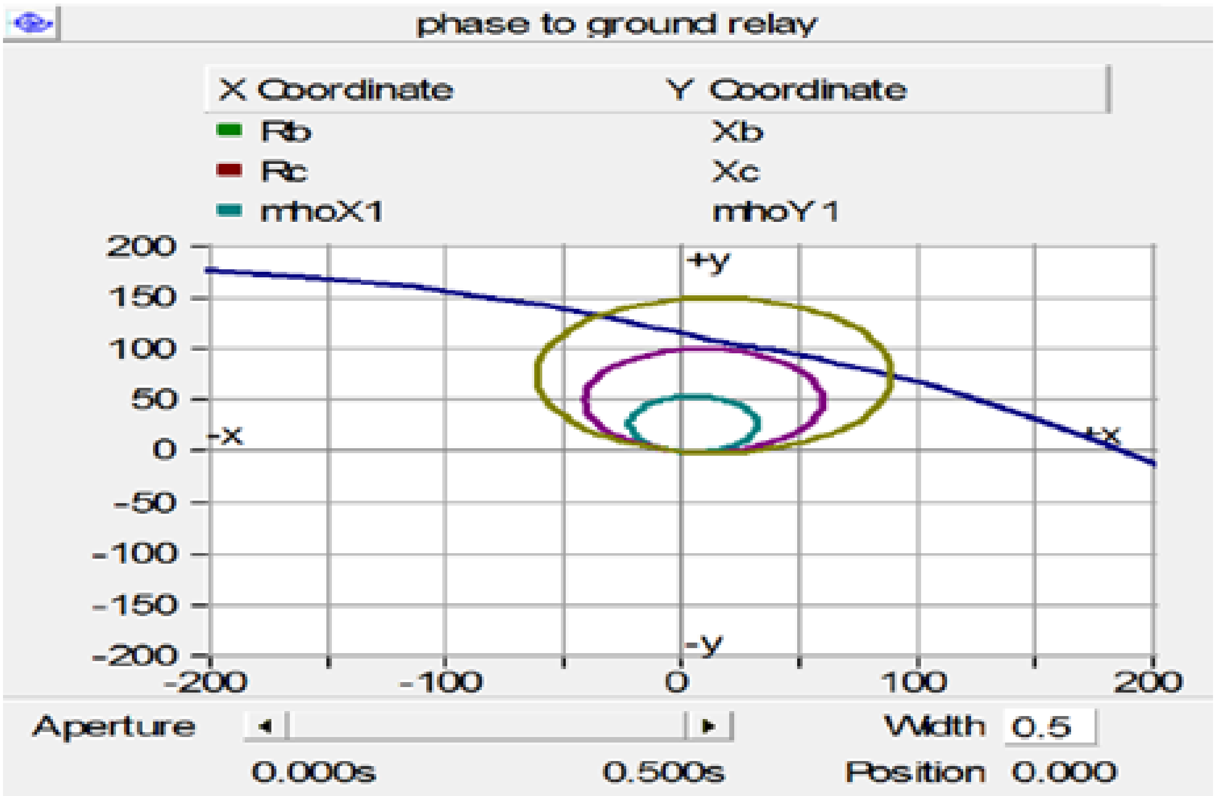

Figure 15.4: Fault at 12 km from Bus-C, Zone 3