



**Channabasaveshwara Institute of Technology**

(Affiliated to VTU, Belgaum & Approved by AICTE, New Delhi)

(NAAC Accredited & ISO 9001:2015 Certified Institution)

NH 206 (B.H. Road), Gubbi, Tumkur – 572 216. Karnataka



**Department of Electrical & Electronics Engineering**

# **BEE601-IPCC LAB MANUAL**

(2025-2026)

**POWER SYSTEM ANALYSIS-1**

**Practical component of IPCC**

**B.E. - VI Semester**

Name: \_\_\_\_\_

USN: \_\_\_\_\_

Batch: \_\_\_\_\_ Section: \_\_\_\_\_



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## **Department of Electrical & Electronics Engineering**

# **POWER SYSTEM ANALYSIS-1**

## **IPCC Lab manual**

**B.E. - VI Semester**

Version 2.1

February 2026

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Partnering in Academic Excellence

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### INSTITUTION VISION

To create centres of excellence in education and to serve the society by enhancing the quality of life through value based professional leadership

### INSTITUTION MISSION

1. To provide high quality technical and professionally relevant education in a diverse learning environment.
2. To provide the values that prepare students to lead their lives with personal integrity, professional ethics and civic responsibility in a global society.
3. To prepare the next generation of skilled professionals to successfully compete in the diverse global market.
4. To promote a campus environment that welcomes and honors women and men of all races, creeds and cultures, values and intellectual curiosity, pursuit of knowledge and academic integrity and freedom.
5. To offer a wide variety of off-campus education and training programmes to individuals and groups.
6. To stimulate collaborative efforts with industries, universities, government and professional societies.
7. To facilitate public understanding of technical issues and achieve excellence in the operations of the institute.

### QUALITY POLICY

Our organization delights customers (students, parents and society) by providing value added quality education to meet the national and international requirements. We also provide necessary steps to train the students for placement and continue to improve our methods of education to the students through effective quality management system, quality policy and quality objectives.



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## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

### DEPARTMENT VISION

To establish a centre of excellence in Electrical and Electronics Engineering education and to foster the development of technically proficient professionals in Electrical Science and related fields while instilling a strong sense of ethics to serve the society efficiently.

### DEPARTMENT MISSION

<b>M1</b>	To provide competent human resources, and to ensure that our students receive top-notch education and mentorship, enabling them to excel in electrical and electronics engineering and allied fields.
<b>M2</b>	To provide quality infrastructure, and to create an environment conducive to innovative learning and research, empowering our students to explore the frontiers of Electrical Sciences and related disciplines.
<b>M3</b>	To foster strong collaborations with industry and research institutions, and to facilitate the exchange of knowledge and ideas, allowing our students and faculty to remain at the cutting edge of technological advancements and practical applications in the field..
<b>M4</b>	To emphasize social responsibility and professional ethics in our curriculum and community engagement, and to prepare our graduates to be conscientious leaders who use their expertise to benefit society, making a positive impact through their work in Electrical Sciences and allied fields..



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### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

## ***‘Instructions to the Candidates’***

1. Students should come with thorough preparation for the experiment/ Program to be executed.
2. Students will not be permitted to attend the laboratory unless they bring the practical record fully completed in all respects pertaining to the experiment/program conducted in the previous class.
3. All the calculations should be made in the observation book. Specimen calculations for one set of readings have to be shown in the practical record.
4. Wherever graphs are to be drawn, A-4 size graphs only should be used and the same should be firmly attached to the practical record.
5. Practical record should be neatly maintained.
6. They should obtain the signature of the staff-in-charge in the observation book after completing each experiment.
7. Theory regarding each experiment should be written in the practical record before procedure in your own words.

# INDEX PAGE

SI.No.	Name of the Program /Experiment	Dates			Manual marks (10)	Record marks (05)	Signature ( Student)	Signature (Faculty)
		Conduction	Repetition	Submission of Record				
<b>Average</b>								

**Note:** If the student fail to attend the regular lab, the program execution has yo be completed in the same week. Otherwise the evaluation will be done for 50% of the maximum marks



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## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

### SYLLABUS WITH COURSE OUTCOMES

#### PRACTICAL COMPONENT OF IPCC

Sl.NO	Experiments
1	Write a program to draw power angle curves for salient and non-salient pole synchronous machines, reluctance power, excitation, EMF and regulation.
2	Write a program to calculate Sag of a transmission line for i) Poles at equal height ii) Poles at unequal height
3	Write a program to determine the efficiency, Regulation, ABCD parameters for short and long transmission line and verify $AD-BC=1$ .
4	Write a program to determine the efficiency, Regulation and ABCD parameters for medium transmission line for i) $\Pi$ - configuration ii) T- Configuration and verify $AD-BC=1$ .
5	Write a program to calculate sequence components of line voltages given the unbalanced phase voltages.
6	Write a program to calculate the sequence components of line currents, given the unbalanced phase currents in a three phase i) 3-wire system ii) 4 wire system.
7	Determination of fault currents and voltages in a single transmission line for i) Single Line to Ground Fault. ii) Line to Line Fault iii) Double Line to Ground Fault Using suitable simulating software package.
8	Determination of fault currents and voltages in a single transmission line for Three phase Fault Using suitable simulating software package.
9	Write a program to obtain critical disruptive voltage for various atmospheric and conductor conditions.
10	Write a program to evaluate transient stability of single machine connected to infinite bus.
<p><b>Course outcomes (Course Skill Set):</b> At the end of the course, the student will be able to:</p> <ol style="list-style-type: none"> <li>1. Model the power system components &amp; construct per unit impedance diagram of power system.</li> <li>2. Analyse three phase symmetrical faults on power system.</li> <li>3. Compute unbalanced phasors in terms of sequence components and vice versa, also develop sequence networks.</li> <li>4. Analyse various unsymmetrical faults on power system.</li> <li>5. Examine dynamics of synchronous machine and determine the power system stability.</li> </ol>	



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## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

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## *Experiment 1*

*Write a program to draw power angle curves for salient and non-salient pole synchronous machines, reluctance power, excitation EMF and regulation.*

**Problem 1.a.** Determine power angle diagram for salient pole synchronous machine connected to infinite bus and obtain excitation emf and regulation. Given  $P=48$  MW,  $pf=0.8$ ,  $V_t=36.64$  kV(L-L),  $X_d=13.5$  ohm and  $X_q= 9.33$  ohm. Use MATLAB Programming.

**%Program to determine power angle diagram for salient pole synchronous machine, excitation emf and regulation**

```

clc;
clear;
p=input('Enter power in MW\n');
pf=input('Enter power factor\n');
vt=input('Enter Line to line voltage in kV\n');
xd=input('Enter xd in ohm\n');
xq=input('xq in ohm\n');
vt_ph=vt*1000/sqrt(3);
pf_a=acos(pf);
q=p*tan(pf_a);
i=(p-j*q)*1e6/(3*vt_ph);
delta=0:1:180;
delta_rad=delta*(pi/180);
if xd~=xq
    eq=vt_ph+(j*i*xq);
    id_mag=abs(i)*sin(angle(eq)-angle(i));
    ef_mag=abs(eq)+((xd-xq)*id_mag);
    e_emf=ef_mag;
    fprintf('\n Excitation emf=%f,e_emf);
    reg=(ef_mag-abs(vt_ph))*100/abs(vt_ph);
    fprintf('\n Percentage regulation=%f,reg);
    pp=ef_mag*vt_ph*sin(delta_rad)/xd;
    rp=vt_ph^2*(xd-xq)*sin(2*delta_rad)/(2*xd*xq);
    net_rp=3*rp/1e6;
    fprintf('\n Net Reluctance Power=%f,net_rp);
    p_sal=pp+rp;
    net_p_sal=3*p_sal/1e6;
    plot(delta,net_rp);
    hold on
    plot(delta,net_p_sal);
    xlabel('delta(deg)');
    ylabel('Three phase power(MW)');
title('Plot: Power angle curve for salient pole synchronous machine');
end

```

**grid**  
**Input**

Enter power in MW

48

Enter power factor

0.8

Enter Line to line voltage in kV

34.64

Enter  $x_d$  in ohm

13.5

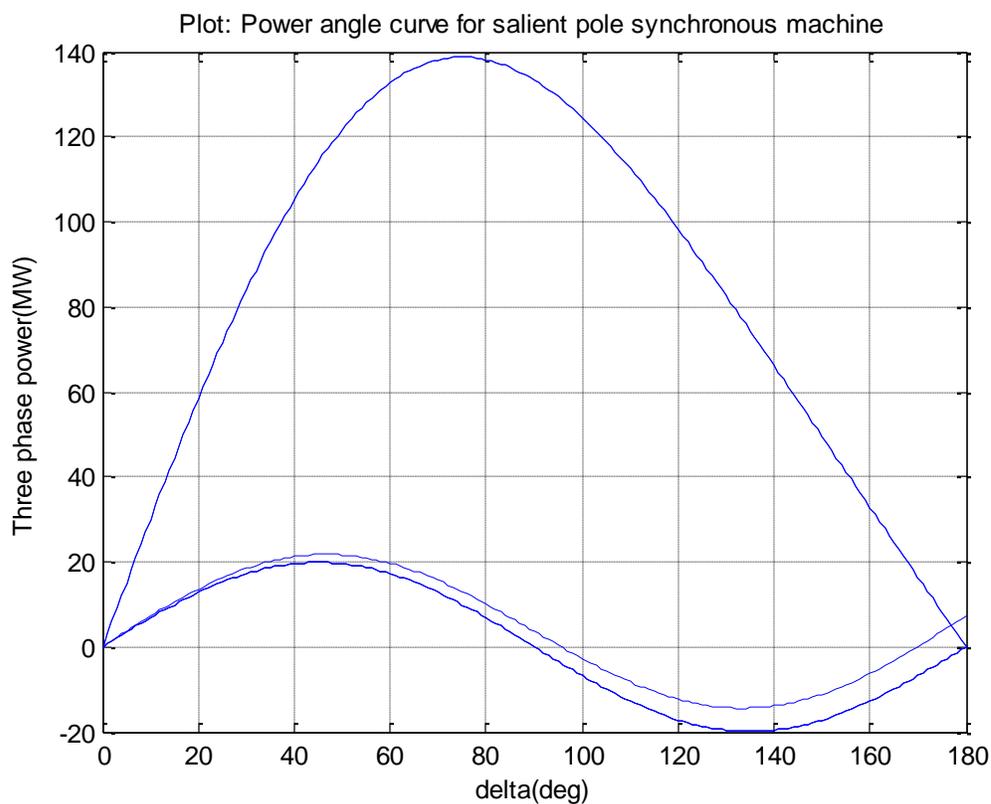
 $x_q$  in ohm

9.33

**Output**

Excitation emf=29999.596799

Percentage regulation=50.002384



**Problem 1.b.** Determine Power angle diagram for non-salient pole synchronous machine connected to infinite bus and obtain excitation emf and regulation. Given  $P=48\text{MW}$ ,  $Pf=0.8$ ,  $V_t=34.64\text{kV(L-L)}$ ,  $X_d=10\text{ ohm}$  and  $X_q=10\text{ ohm}$ . Use MATLAB programming.

**% Program to determine power angle diagram for non-salient pole synchronous machine, excitation emf and regulation.**

```

clc;
clear;
p=input('Enter power in MW\n');
pf=input('Enter power factor\n');
vt=input('Enter Line to line voltage in kV\n');
xd=input('Enter xd in ohm\n');
xq=input('xq in ohm\n');
vt_ph=vt*1000/sqrt(3);
pf_a=acos(pf);
q=p*tan(pf_a);
i=(p-j*q)*1e6/(3*vt_ph);
delta=0:1:180;
delta_rad=delta*(pi/180);
if xd==xq
    ef=vt_ph+(j*i*xd);
    e_emf=abs(ef);
    fprintf('\n Excitation emf=%f',e_emf);
    reg=(abs(ef)-abs(vt_ph))*100/abs(vt_ph);
    fprintf('\n Percentage regulation=%f',reg);
    p_non=abs(ef)*vt_ph*sin(delta_rad)/xd;
    n_power=3*p_non/1e6;
    plot(delta,n_power);
    xlabel('delta(deg)');
    ylabel('Three phase power(MW)');
    title('Plot:Power angle curve for nonsalient pole synchronous m/c');
end
grid

```

### Input

Enter power in MW

48

Enter power factor

0.8

Enter Line to line voltage in kV

34.64

Enter xd in ohm

10

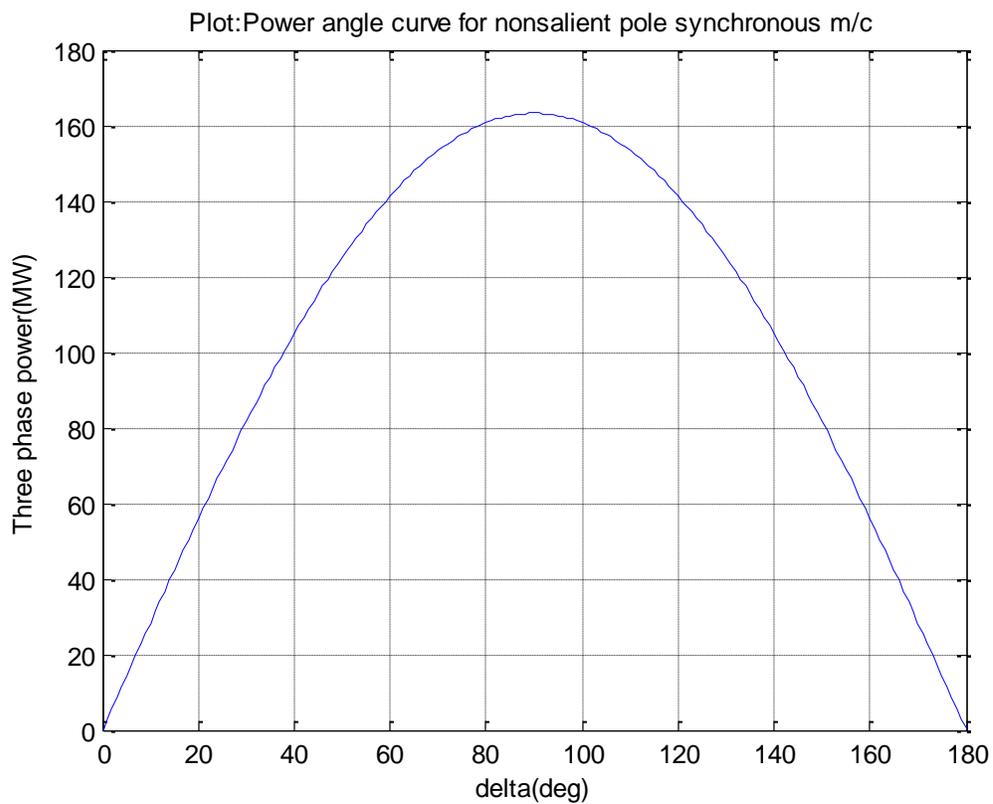
xq in ohm

10

## Output

Excitation emf=27202.617527

Percentage regulation=36.017078



## *Experiment 2*

*Write a program to calculate Sag of a transmission line for i) Poles at equal height ii) Poles at unequal height.*

**Problem 2.a.** *An overhead line has a span of 250 m. The tension in the line is 1500 kg while the conductor weighs 0.75kg/m. Calculate the maximum sag in the conductor. Use MATLAB Programming.*

**%Program to calculate Sag of a transmission line for poles at equal height.**

```
clc;
clear;
```

**% Input Data**

```
L=input('Overhead line span in meter\n');
T=input('Tension in the line in kg\n');
W=input('Conductor weight in kg per meter\n');
```

**% Calculation of Sag**

```
sag=W*L^2/(8*T);
```

**% Output**

```
fprintf('\n Sag=%f m',sag);
```

**Input**

```
Overhead line span in meter
250
Tension in the line in kg
1500
Conductor weight in kg per meter
0.75
```

**Output**

```
Sag of the transmission line=3.906250 m
```

**Problem 2.b.** *The two towers of height 95 m and 70 m respectively support the line conductor at a river crossing. The horizontal distance between the towers is 400 m. If the tension in the conductor is 1100 kg and its weight is 0.8 kg/m, calculate i) Sag at lower support ii) Sag at upper support. Use MATLAB Programming.*

**% Program to calculate Sag of a transmission line for poles at unequal height.**

```
clc;
clear;
```

**% Input Data**

```
H1=input('Height of tower 1 in meter\n');
H2=input('Height of tower 2 in meter\n');
L=input('Total span length in meter\n');
T=input('Tension in the conductor in kg\n');
W=input('Conductor weight in kg per meter\n');
```

**% Calculation of Sag**

```
H=H1-H2;
X1=(L/2)-(T*H)/(W*L);
X2=(L/2)+(T*H)/(W*L);
S1=(W*X1^2)/(2*T);
S2=(W*X2^2)/(2*T);
```

**% Output**

```
fprintf('\n Sag at lower support=%f m',S1);
fprintf('\n Sag at upper support=%f m',S2);
```

**Input**

```
Height of tower 1 in meter
95
Height of tower 2 in meter
70
Total span length in meter
400
Tension in the conductor in kg
1100
Conductor weight in kg per meter
0.8
```

**Output**

```
Sag at lower support=4.731001 m
Sag at upper support=29.731001 m
```

## *Experiment 3*

*Write a program to determine the efficiency, Regulation, ABCD parameters for short and long transmission line and verify  $AD-BC=1$*

**Problem 3.a.** *A 3-phase, 50Hz, 20 km overhead transmission line supplies 1.1MW at 11kV, 0.8 pf lagging. The impedance is  $(0.04+j0.2515)$  ohm/ph/km and negligible admittance. Determine a) ABCD constants b) verify  $AD-BC=1$  c) voltage regulation d) transmission efficiency. Use MATLAB Programming.*

**% Program to obtain ABCD constants, regulation and transmission efficiency for a short line and to verify  $AD-BC=1$**

```
clc;
clear;
```

**% Input data**

```
z=input('Enter the value of impedance in ohms/ph/km\n');
y=input('Enter the value of shunt admittance in mho/ph/km\n');
vr1=input('Enter the value of receiving end L-L voltage in kv\n');
p_3ph=input('Enter the value of 3-ph power in MW\n');
pf=input('Enter the value of receiving end power factor\n');
length=input('Enter the length of transmission line in km\n');
```

**% Determination of ABCD constants**

```
Z=z*length;
Y=y*length;
p=p_3ph*1e6/3;
vr=vr1*1e3/sqrt(3);
A=1
B=Z
C=0
D=1
result=(A*D-B*C);
fprintf('\n AD-BC=%f', result);
```

**% Determination of Regulation**

```
ir1=p/(vr*pf);
ir2=-acos(pf);
ir=ir1*cos(ir2)+j*ir1*sin(ir2);
vs=A*vr+B*ir;
is=C*vr+D*ir;
vreg=(abs(vs)/abs(A)-abs(vr))/abs(vr)*100;
```

```
fprintf("\n Percentage voltage regulation=%f',vreg);
```

### % Determination of efficiency

```
spf=cos(angle(vs*180/pi)-angle(is*180*pi));
rpow=p;
spow=abs(vs)*abs(is)*spf;
eff=(rpow/spow)*100;
fprintf("\n Percentage transmission efficiency=%f\n',eff);
```

### Input for short transmissionline

```
Enter the value of impedance in ohms/ph/km
0.04+0.2515i
Enter the value of shunt admittance in mho/ph/km
0
Enter the value of receiving end L-L voltage in kv
11
Enter the value of 3-ph power in MW
1.1
Enter the value of receiving end power factor
0.8
Enter the length of transmission line in km
20
```

### Output

```
A =
    1
B =
    0.8000 + 5.0300i
C =
    0
D =
    1
```

```
AD-BC=1.000000
```

```
Percentage voltage regulation=4.234647
```

```
Percentage transmission efficiency=98.876404
```

**Problem 3.b.** A 3-phase, 50Hz, 500km overhead transmission line delivers a load of 100MW at 0.8pf lagging and 220kV between the lines. The impedance is  $(0.06944 + j0.39392)$  ohm/ph/km and shunt admittance of  $j2.6 \times 10^{-6}$  mho/ph/km. Find a) ABCD constants b) Sending end voltage

*c) sending end current d) sending end pf e) voltage regulation f) transmission efficiency g) equivalent T/PI circuit constants.*

### **% Program to obtain ABCD constants, regulation and transmission efficiency for a long line and to verify AD-BC=1**

```
clear;
```

#### **% Input data**

```
z=input('Enter the value of impedance in ohms/ph/km\n');
y=input('Enter the value of shunt admittance in mho/ph/km\n');
vr1=input('Enter the value of receiving end L-L voltage in kv\n');
p_3ph=input('Enter the value of 3-ph power in MW\n');
pf=input('Enter the value of receiving end power factor\n');
length=input('Enter the length of transmission line in km\n');
```

#### **% Determination of ABCD constants**

```
Z=z*length;
Y=y*length;
p=p_3ph*1e6/3;
vr=vr1*1e3/sqrt(3);
zc=sqrt(z/y);
gam=sqrt(z*y)*length;
A=cosh(gam)
B=zc*sinh(gam)
C=sinh(gam)/zc
D=A
result=(A*D-B*C);
fprintf('\n AD-BC=%f', result);
```

#### **% Determination of Regulation**

```
ir1=p/(vr*pf);
ir2=-acos(pf);
ir=ir1*cos(ir2)+j*ir1*sin(ir2);
vs=A*vr+B*ir;
is=C*vr+D*ir;
vreg=(abs(vs)/abs(A)-abs(vr))/abs(vr)*100;
fprintf('\n Percentage voltage regulation=%f', vreg);
```

#### **% Determination of efficiency**

```
spf=cos(angle(vs*180/pi)-angle(is*180/pi));
rpow=p;
spow=abs(vs)*abs(is)*spf;
```

```
eff=(rpow/spow)*100;  
fprintf('\n Percentage transmission efficiency=%f\n',eff);
```

### Input for long transmission line

```
Enter the value of impedance in ohms/ph/km  
0.06944+0.39392i  
Enter the value of shunt admittance in mho/ph/km  
2.6e-6i  
Enter the value of receiving end L-L voltage in kv  
220  
Enter the value of 3-ph power in MW  
100  
Enter the value of receiving end power factor  
0.8  
Enter the length of transmission line in km  
500
```

### Output

```
A =  
0.8746 + 0.0216i  
B =  
3.1813e+001 +1.8891e+002i  
C =  
-0.0000 + 0.0012i  
D =  
  
0.8746 + 0.0216i  
  
AD-BC=1.000000  
  
Percentage voltage regulation=46.911862  
  
Percentage transmission efficiency=92.484094
```

## *Experiment 4*

*Write a program to determine the efficiency, Regulation and ABCD parameters for medium transmission line for i)  $\Pi$ - configuration ii) T- Configuration and verify  $AD-BC=1$ .*

**Problem 4.a.** *A 3- phase, 50Hz, 100 km overhead transmission line supplies a load of 40MW at 220kV, 0.9 pf lagging. The impedance is  $(0.35+j1.4)$  ohm/ph/km and shunt admittance of  $j9.3 \times 10^{-6}$  mho/ph/km. Using nominal- $\pi$  method determine a) ABCD constants b) verify  $AD-BC=1$  c) voltage regulation d) transmission efficiency. Use MATLAB Programming.*

**% Program to obtain ABCD constants, regulation and transmission efficiency for a medium line using nominal  $\pi$  method and to verify  $AD-BC=1$**

```
clc;
clear;
```

**% Input data**

```
z=input('Enter the value of impedance in ohms/ph/km\n');
y=input('Enter the value of shunt admittance in mho/ph/km\n');
vrl=input('Enter the value of receiving end L-L voltage in kv\n');
p_3ph=input('Enter the value of 3-ph power in MW\n');
pf=input('Enter the value of receiving end power factor\n');
length=input('Enter the length of transmission line in km\n');
```

**% Determination of ABCD constants**

```
Z=z*length;
Y=y*length;
p=p_3ph*1e6/3;
vr=vrl*1e3/sqrt(3);
A=1+Y*Z/2
B=Z
C=Y*(1+Y*Z/4)
D=A
result=(A*D-B*C);
fprintf('\n AD-BC=%f', result);
```

**% Determination of Regulation**

```
ir1=p/(vr*pf);
ir2=-acos(pf);
ir=ir1*cos(ir2)+j*ir1*sin(ir2);
vs=A*vr+B*ir;
is=C*vr+D*ir;

vreg=(abs(vs)/abs(A)-abs(vr))/abs(vr)*100;
fprintf('\n Percentage voltage regulation=%f',vreg);
```

### **% Determination of efficiency**

```
spf=cos(angle(vs*180/pi)-angle(is*180*pi));
rpow=p;
spow=abs(vs)*abs(is)*spf;
eff=(rpow/spow)*100;
fprintf('\n Percentage transmission efficiency=%f\n',eff);
```

### **Input for medium transmission line(nominal PI method)**

Enter the value of impedance in ohms/ph/km

0.35+1.4i

Enter the value of shunt admittance in mho/ph/km

9.3e-6i

Enter the value of receiving end L-L voltage in kv

220

Enter the value of 3-ph power in MW

40

Enter the value of receiving end power factor

0.9

Enter the length of transmission line in km

100

### Output

A =

0.9349 + 0.0163i

B =

3.5000e+001 +1.4000e+002i

C =

-7.5679e-006 +8.9973e-004i

D =

0.9349 + 0.0163i

AD-BC=1.000000

Percentage voltage regulation=2.666294

Percentage transmission efficiency=97.171995

**Problem 4.b.** A 3- phase, 50Hz, 100 km overhead transmission line supplies a load of 80MW at 220kV, 0.8 pf lagging. The impedance is  $(0.347+j1.97)$ ohm/ph/km and shunt admittance of  $j1.3 \times 10^{-5}$  mho/ph/km. Using nominal-T method determine a) ABCD constants b) verify  $AD-BC=1$  c) voltage regulation d) transmission efficiency. Use MATLAB Programming.

**% Program to obtain ABCD constants, regulation and transmission efficiency for a medium line using nominal T method and to verify AD-BC=1**

```
clc;
clear;
```

**% Input data**

```
z=input('Enter the value of impedance in ohms/ph/km\n');
y=input('Enter the value of shunt admittance in mho/ph/km\n');
vr1=input('Enter the value of receiving end L-L voltage in kv\n');
p_3ph=input('Enter the value of 3-ph power in MW\n');
pf=input('Enter the value of receiving end power factor\n');
length=input('Enter the length of transmission line in km\n');
```

**% Determination of ABCD constants**

```
Z=z*length;
Y=y*length;
p=p_3ph*1e6/3;
vr=vr1*1e3/sqrt(3);
A=1+Y*Z/2
B=Z*(1+Y*Z/4)
C=Y
D=A
result=(A*D-B*C);
fprintf('\n AD-BC=%f', result);
```

**% Determination of Regulation**

```
ir1=p/(vr*pf);
ir2=-acos(pf);
ir=ir1*cos(ir2)+j*ir1*sin(ir2);
vc=vr+ir*(Z/2);
ic=Y*vc;
is=ir+ic;
vs=vc+is*(Z/2);
vreg=(abs(vs)/abs(A)-abs(vr))/abs(vr)*100;
fprintf('\n Percentage voltage regulation=%f', vreg);
```

**% Determination of efficiency**

```
spf=cos(angle(vs*180/pi)-angle(is*180*pi));
rpow=p;
spow=abs(vs)*abs(is)*spf;
eff=(rpow/spow)*100;
```

```
fprintf('\n Percentage transmission efficiency=%f\n',eff);
```

**Input for medium transmission line (nominal T method)**

Enter the value of impedance in ohms/ph/km

0.347+1.97i

Enter the value of shunt admittance in mho/ph/km

1.3e-5i

Enter the value of receiving end L-L voltage in kv

220

Enter the value of 3-ph power in MW

80

Enter the value of receiving end power factor

0.8

Enter the length of transmission line in km

100

**Output**

A =

0.8720 + 0.0226i

B =

3.0257e+001 +1.8478e+002i

C =

0 + 0.0013i

D =

0.8720 + 0.0226i

AD-BC=1.000000

Percentage voltage regulation=36.098701

Percentage transmission efficiency=93.619245

## *Experiment 5*

*Write a program to calculate sequence components of line voltages given the unbalanced phase voltages.*

**Problem 5.** Determine the sequence components of the three voltages,  $V_a=200\angle 0$ ,  $V_b=200\angle 245$  and  $V_c=200\angle 105$ . Use MATLAB Programming.

**% Program to calculate sequence components of line voltages given the unbalanced phase voltages.**

```
clc;
clear;
```

**% Input data**

```
va=input('Enter the voltage in rectangular form of phase a\n');
vb=input('Enter the voltage in rectangular form of phase b\n');
vc=input('Enter the voltage in rectangular form of phase c\n');
a=-0.5+0.866i;
```

**% Calculation of sequence components of line voltages**

```
va1=(va+a*vb+(a^2)*vc)/3;
va2=(va+(a^2)*vb+a*vc)/3;
va0=(va+vb+vc)/3;
```

**% Output**

```
mva1=abs(va1);
ava1=angle(va1)*180/pi;
mva2=abs(va2);
ava2=angle(va2)*180/pi;
mva0=abs(va0);
ava0=angle(va0)*180/pi;
```

```
fprintf('\n The positive sequence component of voltage=%f<%f V',mva1,ava1);
fprintf('\n The negative sequence component of voltage=%f<%f V',mva2,ava2);
fprintf('\n The zero sequence component of voltage=%f<%f V\n',mva0,ava0);
```

**Input**

Enter the voltage in rectangular form of phase a  
200

Enter the voltage in rectangular form of phase b  
-84.52-181.26i

Enter the voltage in rectangular form of phase c  
-51.76+193.18i

### Output

The positive sequence component of voltage= $197.798722<-3.315802$  V

The negative sequence component of voltage= $20.144741<158.242004$  V

The zero sequence component of voltage= $21.608447<10.595766$  V

## *Experiment 6*

*Write a program to calculate the sequence components of line currents, given the unbalanced phase currents in a three phase i) 3-wire system ii) 4 wire system.*

**Problem 6.i)** *In a 3 phase, 3 wire system, the line currents are  $I_a=100\angle 0^\circ$  A,  $I_b=100\angle -100^\circ$  A and  $I_c=128.56\angle 130^\circ$ . Determine the sequence components of line currents. Use MATLAB Programming.*

**% Program to calculate sequence components of line currents given the unbalanced phase currents in a three phase 3-wire system.**

```
clc;
clear;
```

```
% Input data
```

```
ia=input('Enter the current in rectangular form of line a\n');
ib=input('Enter the current in rectangular form of line b\n');
ic=input('Enter the current in rectangular form of line c\n');
a=-0.5+0.866i;
```

```
% Calculation of sequence components of line voltages
```

```
ia1=(ia+a*ib+(a^2)*ic)/3;
ia2=(ia+(a^2)*ib+a*ic)/3;
ia0=(ia+ib+ic)/3;
```

```
% Output
```

```
mia1=abs(ia1);
aia1=angle(ia1)*180/pi;
mia2=abs(ia2);
aia2=angle(ia2)*180/pi;
mia0=abs(ia0);
aia0=angle(ia0)*180/pi;
```

```
fprintf('\n The positive sequence component of line current=%f<%f V',mia1,aia1);
fprintf('\n The negative sequence component of line current=%f<%f V',mia2,aia2);
fprintf('\n The zero sequence component of line current=%f<%f V\n',mia0,aia0);
```

### **Input**

Enter the current in rectangular form of line a  
100

Enter the current in rectangular form of line b  
-17.36+-98.48i

Enter the current in rectangular form of line c  
-82.64+98.48i

### Output

The positive sequence component of line current= $108.503718\angle 10.002215$  V

The negative sequence component of line current= $20.053980\angle -109.991415$  V

The zero sequence component of line current= $0.000000\angle 0.000000$  V

**Problem 6.ii)** In a 3 phase, 4 wire system, the line currents are  $I_a=20\angle 0^\circ A$ ,  $I_b=20\angle -100^\circ A$  and  $I_c=22\angle 126.48^\circ$ . Determine the sequence components of line currents and neutral current. Use MATLAB Programming.

**% Program to calculate sequence components of line currents given the unbalanced phase currents in a three phase 4-wire system.**

```
clc;
clear;
```

**% Input data**

```
ia=input('Enter the current in rectangular form of line a\n');
ib=input('Enter the current in rectangular form of line b\n');
ic=input('Enter the current in rectangular form of line c\n');
a=-0.5+0.866i;
```

**% Calculation of sequence components of line voltages**

```
ia1=(ia+a*ib+(a^2)*ic)/3;
ia2=(ia+(a^2)*ib+a*ic)/3;
ia0=(ia+ib+ic)/3;
in=3*ia0;
```

**% Output**

```
mia1=abs(ia1);
aia1=angle(ia1)*180/pi;
mia2=abs(ia2);
aia2=angle(ia2)*180/pi;
mia0=abs(ia0);
aia0=angle(ia0)*180/pi;
min=abs(in);
ain=angle(in)*180/pi;
```

```
fprintf('\n The positive sequence component of line current=%f<%f A',mia1,aia1);
fprintf('\n The negative sequence component of line current=%f<%f A',mia2,aia2);
fprintf('\n The zero sequence component of line current=%f<%f A',mia0,aia0);
fprintf('\n The neutral current=%f<%f A\n',min,ain);
```

**Input**

```
Enter the current in rectangular form of line a
20
Enter the current in rectangular form of line b
-3.47-19.69i
```

Enter the current in rectangular form of line c  
-13.07+17.68i

### Output

The positive sequence component of line current= $20.447959\angle 8.738225$  A  
The negative sequence component of line current= $2.792399\angle -119.244479$  A  
The zero sequence component of line current= $1.333821\angle -30.153369$  A  
The neutral current= $4.001462\angle -30.153369$  A

## *Experiment 7*

*Write a program to determine fault currents in a single transmission line for i) Single Line to Ground Fault. ii) Line to Line Fault iii) Double Line to Ground Fault.*

*Problem 7. A three-phase generator with an open circuit voltage of 400V is subjected to an LG fault through fault impedance of  $j2$  ohm. Determine the fault current if  $Z_1=j4$  ohm,  $Z_2=j2$  ohm and  $Z_0=j1$  ohm. Repeat the problem for LL and LLG fault. Use MATLAB Programming.*

**% Program to determine fault currents in a single transmission line for LG, LL and DLG fault.**

```
clc;
clear;
```

**% Input data**

```
z1=input('Enter positive sequence impedance\n');
z2=input('Enter negative sequence impedance\n');
z0=input('Enter zero sequence impedance\n');
zf= input('Enter fault impedance\n');
vl=input('Enter open circuit line voltage\n');
```

**% Calculation of fault current for LG fault**

```
vph=400/sqrt(3);
iao=vph/(z1+z2+z0+3*zf);
if_lg=3*abs(iao);
fprintf('\n Fault Current for LG fault=%f A',if_lg);
```

**% Calculation of fault current for LL fault**

```
ia1=vph/(z1+z2+zf);
if_ll=sqrt(3)*abs(ia1);
fprintf('\n Fault Current for LL fault=%f A',if_ll);
```

**% Calculation of fault current for LLG fault**

```
a=z2*(z0+3*zf);  
b=z2+z0+3*zf;  
ia1=vph/(z1+a/b);  
iao=-ia1*z2/(z2+z0+3*zf);  
if_llg=3*abs(iao);  
fprintf('\n Fault Current for LLG fault=%f A\n',if_llg);
```

### Input

Enter positive sequence impedance

4i

Enter negative sequence impedance

2i

Enter zero sequence impedance

1i

Enter fault impedance

2i

Enter open circuit line voltage

400

### Output

Fault Current for LG fault=53.293871 A

Fault Current for LL fault=50.000000 A

Fault Current for LLG fault=27.712813 A

## *Experiment 8*

**Write a program to determine fault currents and voltages in a single transmission line for Three phase Fault.**

**Problem 8.** A synchronous generator and motor are rated for 30 MVA, 13.2 kV and both have sub transient reactance of 20%. The line connecting them has a reactance of 10% on the base of machine ratings. The motor is drawing 20000 kW at 0.8 pf leading. The terminal voltage of the motor is 12.8 kV. When a symmetrical three phase fault occurs at motor terminals, find the sub transient current in generator, motor and at the fault point.

% Program to determine fault currents and voltages for three phase fault

```
clc;
clear;
```

% Input data

```
sb=input('Enter the base MVA value\n');
vb=input('Enter the base kV value\n');
p=input('Enter the power drawn by the motor in kW\n');
line_reac=input('Enter the value of line reactance in pu\n');
subtrans_reac=input('Enter the value of subtransient reactance in pu\n');
vpf=input('Enter the terminal voltage of the motor in kV\n');
pf=input('Enter power factor\n');
```

% To determine the base current and load current

```
vpf_pu=vpf/vb;
IB=sb*1e6/((sqrt(3)*vb*1e3));
IL1=p*1e3/((sqrt(3)*vpf*1e3*pf));
IL2=acos(pf);
IL=IL1*cos(IL2)+j*IL1*sin(IL2);
IL_pu=IL/IB;
```

% To determine subtransient voltages, currents and fault current

```
Eg=subtrans_reac*IL_pu*i+line_reac*IL_pu*i+vpf_pu;
mEg=abs(Eg);
aEg=angle(Eg)*180/pi;
Em=vpf_pu-subtrans_reac*IL_pu*i;
mEm=abs(Em);
aEm=angle(Em)*180/pi;
fprintf('\n Subtransient voltage Eg=%f<%f pu\n',mEg,aEg);
```

```
fprintf('Subtransient voltage Em=%f<%f pu\n',mEm,aEm);
Ig=Eg/((subtrans_reac+line_reac)*i);
Im=Em/(subtrans_reac*i);
If=Ig+Im;
mIf=abs(If);
aIf=angle(If)*180/pi;
fprintf('Current at the fault point,If=%f<%f pu\n',mIf,aIf);
```

### Input

Enter the base MVA value

30

Enter the base kV value

13.2

Enter the power drawn by the motor in kW

20000

Enter the value of line reactance in pu

0.1

Enter the value of subtransient reactance in pu

0.2

Enter the terminal voltage of the motor in kV

12.8

Enter power factor

0.8

### Output

Subtransient voltage Eg=0.840702<14.201381 pu

Subtransient voltage Em=1.081598<-7.303591 pu

Current at the fault point,If=8.080808<-90.000000 pu

## *Experiment 9*

*Write a program to obtain critical disruptive voltage for various atmospheric and conductor conditions.*

**Problem 9.** *A 3 phase, 50 Hz, 132kV transmission line consists of conductors of 1.17cm diameter and spaced equilaterally at a distance of 300cm. The conductors have smooth surface with irregularity factor,  $m_0=0.96$ . The barometric pressure is 72 cm of Hg and the temperature is  $20^{\circ}\text{C}$ . Determine critical disruptive voltage under fair and foul weather conditions. The breakdown strength of air is 30kv/cm(rms). Use MATLAB Programming.*

**% Program to obtain critical disruptive voltage for various atmospheric and conductor conditions.**

```
clc;
clear;
```

**% Input data**

```
b=input('Enter barometric pressure in cm\n');
t=input('Enter temperature in degree celsius\n');
mo=input('Enter irregularity factor\n');
dis=input('Enter distance between conductors in cm\n');
dia=input('Enter diameter of conductor in cm\n');
go_rms=input('Enter breakdown strength of air in kv/cm\n');
```

**% To determine Critical Disruptive Voltage under fair weather condition**

```
r=dia/2;
delta=3.92*b/(273+t);
go=go_rms/sqrt(2);
vd=r*delta*go*mo*log(dis/r);
fprintf('Disruptive Critical Voltage in kv per phase under fair weather condition =%f kV/ph\n',vd);
```

**% To determine Critical Disruptive Voltage under foul weather condition**

```
vd_foul=0.8*vd;
fprintf('Disruptive Critical Voltage in kv per phase under foul weather condition =%f kV/ph\n',vd_foul);
```

**Input**

Enter barometric pressure in cm

72

Enter temperature in degree celsius

20

Enter irregularity factor

0.96

Enter distance between conductors in cm

300

Enter diameter of conductor in cm

1.17

Enter breakdown strength of air in kv/cm

30

### Output

Disruptive Critical Voltage in kv per phase under fair weather condition =71.608361 kV/ph

Disruptive Critical Voltage in kv per phase under foul weather condition =57.286689 kV/ph

## *Experiment 10*

*Write a program to evaluate transient stability of single machine connected to infinite bus.*

**Problem 10.** *An equivalent generator connected to a 50 Hz infinite bus has steady state power limits before, during & after a fault is cleared as 2 pu, 0.5 pu and 1.5 pu. Calculate the critical clearing angle if the initial load is 1 pu. Use MATLAB Programming.*

**% Program to evaluate transient stability of single machine connected to infinite bus**

```

clc;
clear;

% Input data

pm1=input('Enter steady state power limit before the fault is cleared\n');
pm2=input('Enter steady state power limit during the fault is cleared\n');
pm3=input('Enter steady state power limit after the fault is cleared\n');
ps=input('Enter initial load in pu\n');
deltao=asin(ps/pm1)*180/pi;
deltam=180-asin(ps/pm3)*180/pi;
nr=pi/180*ps*(deltam-deltao)-pm2*cos(deltao*pi/180)+pm3*cos(deltam*pi/180);
dr=pm3-pm2;
cosdeltacc=nr/dr;
deltacc=acos(cosdeltacc)*180/pi;
fprintf('\n Critical clearing angle =%f degree\n',deltacc);

```

### **Input**

```

Enter steady state power limit before the fault is cleared
2
Enter steady state power limit during the fault is cleared
0.5
Enter steady state power limit after the fault is cleared
1.5
Enter initial load in pu
1

```

### **Output**

```

Critical clearing angle =70.292437degree

```

### *Model Questions*

1. Write a program to plot the power–angle characteristics of a non-salient pole synchronous machine.
2. Modify the program to include reluctance power for a salient pole synchronous machine.
3. Plot and compare power angle curves for salient and non-salient pole machines.
4. Determine the maximum power transfer for both machines.
5. Study the effect of excitation on power angle characteristics.
6. Explain the regulation of synchronous machine using power angle curves.
7. Write a program to calculate sag for conductors with equal height supports.
8. Write a program to calculate sag for conductors with unequal height supports.
9. Study the effect of span length on sag.
10. Determine tension in the conductor.
11. Plot sag vs span length curve.
12. Write a program to determine efficiency and voltage regulation of a short transmission line.
13. Determine ABCD parameters for a long transmission line.
14. Verify the condition  $AD - BC = 1$ .
15. Study the effect of load power factor on regulation.
16. Compare efficiency of short and long transmission lines.
17. Write a program to calculate ABCD parameters using nominal  $\pi$  model.
18. Write a program to calculate ABCD parameters using nominal T model.
19. Determine efficiency and regulation of medium transmission line.
20. Verify  $AD - BC = 1$  for both models.
21. Compare  $\pi$  and T configurations.
22. Write a program to calculate sequence components of unbalanced voltages.
23. Determine positive, negative and zero sequence voltages.
24. Reconstruct phase voltages from sequence components.
25. Study symmetrical and unsymmetrical conditions
26. Write a program to calculate sequence components of unbalanced currents.
27. Determine sequence currents for 3-phase 3-wire system.
28. Determine sequence currents for 3-phase 4-wire system.
29. Compare sequence components in both systems
30. Determine fault current for single line to ground fault.
31. Determine fault current for line to line fault.
32. Determine fault current for double line to ground fault.
33. Analyze fault voltages using simulation software.
34. Compare severity of different faults.
35. Determine fault current during a three-phase fault.
36. Calculate fault MVA.
37. Analyze fault voltages and currents using simulation.
38. Compare symmetrical and unsymmetrical faults.
39. Write a program to calculate critical disruptive voltage.
40. Study effect of atmospheric conditions.
41. Study effect of conductor radius.
42. Compare fair and stormy weather conditions.

43. Plot critical disruptive voltage vs conductor spacing
44. Write a program to evaluate transient stability of SMIB system.
45. Plot swing curve for different fault clearing times.
46. Determine critical clearing angle.
47. Determine critical clearing time.
48. Study effect of inertia constant on stability

VIVA QUESTIONS

1. What is power angle ( $\delta$ )?
2. What is meant by pull-out power?
3. Why does salient pole machine have two components of power?
4. Define reluctance power.
5. What happens when excitation is increased?
6. Why is power angle limited to  $90^\circ$ ?
7. Difference between salient and non-salient pole machines.
8. What is synchronous stability limit?
9. What is sag?
10. Why is sag necessary in transmission lines?
11. Factors affecting sag?
12. What is the effect of temperature on sag?
13. Why is sag more in summer?
14. Difference between sag in equal and unequal supports.
15. What is stringing chart?
16. What is voltage regulation?
17. Define efficiency of transmission line.
18. What are ABCD parameters?
19. Why capacitance is neglected in short lines?
20. What is Ferranti effect?
21. Why  $AD - BC = 1$ ?
22. Difference between short and long transmission lines.
23. Why medium transmission line models are required?
24. Difference between  $\pi$  and T models.
25. Which model is preferred and why?
26. Where is shunt capacitance placed in  $\pi$  model?
27. What is charging current?
28. What is Ferranti effect?
29. What are symmetrical components?
30. Who proposed symmetrical component theory?
31. Define positive sequence components.
32. What is zero sequence voltage?
33. Why sequence components are used?
34. When do negative sequence components occur?
35. Applications of symmetrical components.
36. Difference between 3-wire and 4-wire system.
37. Why zero sequence current does not flow in 3-wire system?
38. What is neutral current?
39. Define negative sequence current.
40. Effect of unbalanced load on machines
41. What is a fault?
42. Types of unsymmetrical faults.
43. Which fault is most common?
44. Which fault is most severe?

45. Why sequence networks are interconnected?
46. What is fault level?
47. Purpose of grounding?
48. What is a three-phase fault?
49. Why it is called symmetrical fault?
50. Why it is most severe?
51. What is short circuit capacity?
52. What is per unit system?
53. Advantages of per unit system.
54. What is fault impedance?
55. What is corona?
56. What is critical disruptive voltage?
57. Effects of corona.
58. How corona can be reduced?
59. What is visual corona?
60. Difference between disruptive and visual corona.
61. Why bundled conductors are used?
62. What is power system stability?
63. Types of stability.
64. What is swing equation?
65. What is critical clearing time?
66. What is infinite bus?
67. Effect of fault duration on stability.
68. How stability can be improved?