RV College of Engineering®

Department of Electrical and Electronics Engineering

LAB MANUAL

Course: POWER SYSTEM ANALYSIS LAB – 21EE72

(Scheme-2021)

Name:

USN:

Faculty Incharge

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Head of the Department

Dr. S.G.Srivani

2024

DEPATRMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

RV COLLEGE OF ENGINEERING®
(AUTONOMOUS UNDER VTU) BANGALORE-560059

Laboratory Certificate

This is to certify that Mr. / Ms. ____________________________bearing USN _______________

has satisfactorily completed the course of Experiments in Practical __________________________

in __________semester, prescribed by the department during the year ________________________.

Marks	
Maximum	**Obtained**
50	

Marks in words	

Signature of the Faculty

Signature of the H.O.D

Instructions to students:

1. All the programs are developed in MATLAB/Simulink and MiPOWER and ETAP software package.

2. The students are instructed to go through the algorithm, understand the logic and the corresponding Matlab code, before coming to the lab class and answer the oral questions asked by the teacher in charge.

3. The students are instructed to write the programs in the data sheet along with input given in the manual before coming to the lab class.

4. The students are instructed to write algorithm/flowcharts on the L.H.S of the record book along with input and corresponding output. Program and the relevant theory can be written on R.H.S.

5. If a student is absent to a class he/she has to come prepared for the regular program instead of the missed program. A maximum of two of the missed programs can be completed in the repetition class.

6. A student can miss only one class under genuine circumstances.

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PROGRAM OUTCOMES (POs)

PO1: Engineering Knowledge: Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop to the solution of complex engineering problems.

PO2: Problem Analysis: Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)

PO3: Design/Development of Solutions: Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5)

PO4: Conduct Investigations of Complex Problems: Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8).

PO5: Engineering Tool Usage: Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling recognizing their limitations to solve complex engineering problems. (WK2 and WK6)

PO6: The Engineer and The World: Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7).

PO7: Ethics: Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)

PO8: Individual and Collaborative Team work: Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.

PO9: Communication: Communicate effectively and inclusively within the community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences

PO10: Project Management and Finance: Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multidisciplinary environments.

PO11: Life-Long Learning: Recognize the need for, and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change. (WK8)

VISION

Attain technical excellence in Electrical and Electronics Engineering through graduate programs and interdisciplinary research related to sustainability in power, energy and allied fields.

MISSION

1. To provide technical education that combines rigorous academic study and the excitement of innovation enabling the students to engage in lifelong learning
2. To establish Center of Excellence in sustainable electrical energy, smart grids and systems.
3. To establish tie-ups with industries and institutions of repute and to foster building up of a wide knowledge base to keep in tune with upcoming technologies.
4. To motivate commitment of faculty and students to collate, generate, disseminate, preserve knowledge and to work for the benefit of society.
5. To develop simple, appropriate and cost effective inclusive technologies which are instrumental in the up-liftment of rural society.

Course outcomes:

Course Outcomes: After completing the course, the students will be able to	
CO1	Analyse the fundamentals concepts and representation of power system and operation under various conditions.
CO2	Apply numerical techniques to evaluate the power flows, optimum generation schedule and stability of power systems.
CO3	Analyse the power system behaviour under fault conditions and to obtain load flow solution for stability analysis.
CO4	Evaluate & Design for the given power system problems using software simulation tools.

Laboratory CIE Evaluation (50 Marks):

Conduction of laboratory exercises, lab report, observation, and analysis (30 Marks), lab test (10 Marks) and Innovative Experiment/ Concept Design and Implementation (10 Marks) adding up to 50 Marks. THE FINAL MARKS WILL BE 50 MARKS

Laboratory SEE Evaluation (50 Marks):

Experiment write up (10 Marks), Conduction with proper results (30 marks) and Viva (10 marks). Total SEE for laboratory is 50 marks.

CONTENT

EVALUATION

No.	Experiments	Data sheet+ Calculation (4M)	Results + Observations (4M)	Viva (2M)	Total (10)
1	Formation of Y-BUS with off-nominal turns ratio by direct method				
2	Formation of Y-BUS using singular transformation (i) with half line charging admittance (ii) with mutual coupling				
3	LFA by Gauss-Siedel method using MATLAB				
4	LFA by GS, NR and FDLF methods using MiPower software				
5	LFA by GS, NR and FDLF methods using ETAP software package				
6	Determination of Bus currents, Bus power and Lineflows using MATLAB				
7	Short circuit studies using MiPower software package				
8	Transient Stability Studies using MiPower software				
9	Swing Curve using Euler's method in MATLAB				
10	Swing Curve using Runge Kutta method in MATLAB				
11	Economical generator scheduling for thermal power plants with and without losses in MATLAB				
12	Fault scenario Simulation a) Fault scenario simulation in a feeder b) Fault scenario simulation in a Transformer/ bus				
13	**INNOVATIVE EXPERIMENT (10M)** • Modelling of Renewable Energy System in ETAP or • Fault Analysis in PV systems				
	RECORD TOTAL (30M)				
	LAB TEST (10M)				
	TOTAL (50M)				

Signature of the Faculty

EXPERIMENT 1

Formation of Y_{bus} using Direct/Inspection Method

Aim: Form Y_{bus} with off-nominal turns ratio by direct method using MATLAB.

Line Data:

Line No.	From bus- To bus (p-q)	Line Impedance (z)	HLC adm.	Off-nominal turns ratio (a)
1	5-4	0.02+0.06i	0.03i	0.9
2	5-1	0.08+0.24i	0.025i	1.0
3	4-1	0.06+0.18i	0.02i	1.0
4	4-2	0.06+0.18i	0.02i	1.0
5	4-3	0.04+0.12i	0.015i	1.0
6	1-2	0.01+0.03i	0.01i	0.8
7	2-3	0.08+0.24i	0.025i	1.0

Algorithm:

1. Read the no. of buses(nbus) and no. of lines (nline)
2. Read from bus no, to bus no, line impedance and half line charging admittance(hlc) and off-nominal turns ratio(a) of each line
3. Convert line impedance to admittance(y) of each line
4. Repeat step i to iii for K=1 to nline
   - i. P = from bus no. q=to bus no.
   - ii. Set y = y/a
   - iii. Diagonal elements:

     Ypp = Ypp + y + hlc+((1-a)/a)*y

     Yqq = Yqq + y + hlc+(a-1)*y
   - iv. Off diagonal elements:

     Ypq = Ypq – y

     Yqp = Ypq
5. Display Y bus
6. Stop

Program:

```
%        p q             z           hlc(y/2)    a
    D= [5  4    0.02+0.06i      0.03i        0.9
         5 1   0.08+0.24i       0.025i       1.0
         4 1   0.06+0.18i        0.02i       1.0
         4 2   0.06+0.18i        0.02i       1.0
         4 3   0.04+0.12i        0.015i      1.0
         1 2   0.01+0.03i        0.01i       0.8
         2 3   0.08+0.24i        0.025i      1.0   ];

fb=D(:,1);
tb=D(:,2);
Z=D(:,3);
hlc=D(:,4);
a=D(:,5);y=1./Z;
nbus=max(max(fb),max(tb));
Y=zeros(nbus);
nline=length(fb);
for
k=1:nline,
p=fb(k);q=tb(k);
y(k)=y(k)/a(k);
Y(p,p)=Y(p,p)+y(k)+hlc(k)+(1-a(k))/a(k)*y(k);
Y(q,q)=Y(q,q)+y(k)+hlc(k)+(a(k)-1)*y(k);
Y(p,q)=Y(p,q)-y(k);
Y(q,p)=Y(p,q);
end
 Ybus=Y
```

Exercise:

1. Repeat the exercise for the same data with transformers replaced by transmission lines
2. Modify the program without half line charging admittances.
3. Determine Y-bus for the following data

Line No.	Between buses	Line impedance	Half line charging admittance
1	1-4	0.08+ j0.37	0.007
2	1-6	0.123+j0.518	0.010
3	2-3	0.723 + j1.05	0.0
4	2-5	0.282 +j0.64	0.0
5	4-3	0.0 + j0.133	0.0
6	4-6	0.097+ j0.407	0.0076
7	6-5	0.0+ j0.3	0.0

4.Determine Ybus in data given in the program if a shunt capacitor of admittance j0.008 isconnected at bus no 3.

5.Modify Ybus if an identical parallel line is added between 2-3.

Calculations:

Results:

Inference:

EXPERIMENT 2

Formation of Y_{bus} using Singular Transformation Method

Aim: a) Form Y_{bus} by Singular transformation method with Half Line Charging Admittance using MATLAB.

Line Data:

Line No.	From bus- To bus (p-q)	Line Impedance (z)	HLC adm.
1	1-2	0.02+0.06i	0.03i
2	1-3	0.08+0.24i	0.025i
3	2-3	0.06+0.18i	0.02i
4	2-4	0.06+0.18i	0.02i
5	2-5	0.04+0.12i	0.015i
6	3-4	0.01+0.03i	0.01i
7	4-5	0.08+0.24i	0.025i

Algorithm:

1. Read no. of buses(nbus) and no. of lines(nline).
2. Initialize shunt admittance matrix to zeros.
3. Repeat step no i. to step no iv for I=1 to nline.
   i. Read line data i.e., frombusno, tobus no, Zseries, half line charging.
   ii. Shunt admittance [from bus]=shunt admittance [from bus]+half line charging.
   iii. Shunt admittance [to bus]=shunt admittance [to bus]+half line charging.
   iv. Series admittance [I]=1/series impedance [I].
4. Form the incidence matrix A

   (i) Initialize all the elements of matrix A of size [(nbus + nline) x nbus] to zeros

   (ii) Form $A = \dfrac{AI}{AA}$ Where AI is identity matrix of size (nbus x nbus)

   AA is a matrix of size (nline x nbus) and elements of AA = [aij] Where aij = 0 if i^{th} branch is not incident on j^{th} bus.

   aij = 1 if i^{th} branch is incident to and oriented away from j^{th} bus. aij = -1 if i^{th} branch is incident to and oriented away from j^{th} bus.

5. Form Yprimitive matrix

Initialize all elements of matrix Ypr of size (nbus+nline x nbus+nline) to zeros

$$\text{Form Ypr} = \left.\begin{array}{c|c} y & yy \\ \hline yy' & y' \end{array}\right.$$

Where Y is a matrix of size (nbus x nbus) with diagonal elements y= total shunt admittance at bus i and all other elements being zeros.yy is a matrix of size (nbus x nline) with all elements being zeros.

y' is matrix of size (nline x nline) with diagonal elements of y' =Yseries of line i=1/Zseries of line i.

yy' is matrix of size (nline x nbus) with all elements being zeros.

6. Display A matrix & Ypr matrix.
7. Form Transpose of matrix A i.e., A^T.
8. Form $A^TY = A^T * \text{Ypr}$.
9. Form Ybus = A^TY *A and display.
10. Form Zbus = $[\text{Ybus}]^{-1}$ and display.
11. Stop

Program:

% Formation of Y_{bus} using singular transformation method without mutual coupling:

```
%    p   q        Z          hlc(Adm)
D= [1   2   0.02+0.06i     0.03i
    1   3   0.08+0.24i     0.025i
    2   3   0.06+0.18i     0.02i
    2   4   0.06+0.18i     0.02i
    2   5   0.04+0.12i     0.015i
    3   4   0.01+0.03i     0.01i
    4   5   0.08+0.24i     0.025i];

fb=D(:,1);
tb=D(:,2);
Z=D(:,3);
hlcy=D(:,4);
y=1./Z;
nbus=max(max(fb),max(tb));
Y=zeros(nbus);
nline=length(fb);
nlb=nline+nbus;
A=zeros(nlb,nbus);
for
k=1:nbus
A(k,k)=1;
end
for k=1:nline
A(nbus+k,fb(k))=1;
A(nbus+k,tb(k))=-1;
end
```

```
sh=zeros(nbus);
for k=1:nline
sh(fb(k))=sh(fb(k))+hlcy(k);
sh(tb(k))=sh(tb(k))+hlcy(k);
end
ypr=zeros(nlb,nlb);
for k=1:nbus
ypr(k,k)=sh(k);
end
for k=1:nline
ypr(nbus+k,nbus+k)=y(k);
end
format short;
Ybus=A'*ypr*A
```

Exercise:

1. Can this method be used with transformers? Justify.
2. Determine Ybus for data of exercise 2 in first program and compare results with that obtainedby direct method.
3. Determine Ybus for the following data

Line	R	X	hlc
1-2	0.05	0.15	0.0025
1-3	0.1	0.3	0.03
2-3	0.15	0.45	0.05
2-4	0.10	0.30	0.0
3-4	0.05	0.15	0.0125

Calculations:

Results:

Inference

Aim: b) Form Y_{bus} by Singular Transformation Method with MutualCoupling in MATLAB.

Line Data:

Line No.	From bus- To bus (p-q)	Line Impedance (z)	Mno.	Mutual impedance
1	0-1	0.6i	0	0
2	0-2	0.5i	1	0.1i
3	2-3	0.5i	0	0
4	0-1	0.4i	1	0.2i
5	1-3	0.2i	0	0

Algorithm:

1. Read no. of buses(nbus) and no. of lines (nline).
2. Road line data i.e., Frombus no, tobus no, Zseries, mutual line no, Zmutual at all lines.
3. Form bus incidence matrix A
   i. Initialize all the elements of A of size (nline x nline) to zeros
   ii. Form A = [aij]
   Where, aij = 0 if i^{th} branch is not incident on j^{th} bus.

   aij = 1 if i^{th} branch is incident to and oriented away from j^{th} bus. aij = -1 if i^{th} branch is incidentto and oriented away from j^{th} bus.
4. Form Zprimitive matrix, Zpr
   i. Initialize all the elements of Zpr of size (nline x nline) to zeros
   ii. The diagonal elements of Zpr are assigned with respective Zseries i.e.,
   Zpr (i, i) = Zseries of i^{th} line
   iii. The off diagonal element is zero if the line i has no mutual coupling with line j
   iv. The off diagonal element Zpr (i, j) = Zmutual if the line i has mutual coupling withline j
5. Form Y primitive matrix Ypr = $[Zpr]^{-1}$
6. Display A matrix & Ypr matrix.
7. Form Transpose of matrix A i.e., AT.
8. Form ATY = AT *Ypr.
9. Form Ybus = ATY * A and display.
10. Form Zbus = $[Ybus]^{-1}$ and display.
11. Stop

Program:

```
% formation of ybus using singular transformation method with mutual coupling &without
  line charging:

  %        p   q    Z      mno    mutual impedance
      D=[  0   1   0.6i     0          0
           0   2   0.5i     1          0.1i
           2   3   0.5i     0          0
           0   1   0.4i     1          0.2i
```

```
1    3   0.2i       0            0  ];

p=D(:,1);
q=D(:,2);
Z=D(:,3);
mno=D(:,4);
zmc=D(:,5);
nbus=max(max(p),max(q));
Y=zeros(nbus);
nline=length(p);
A=zeros(nline,nbus);
 for k=1:nline,
        if(q(k)==0)
        A(k,p(k))=1;
        elseif(p(k)==0)
        A(k,q(k))=-1;
        end
        if(p(k)~=0 & q(k)~=0)
        A(k,p(k))=1;
        A(k,q(k))=-1;
        end
  end
     zpr=zeros(nline,nline);
for k=1:nline
zpr(k,k)=Z(k);
        if(mno(k))
        zpr(k,mno(k))=zmc(k);
        zpr(mno(k),k)=zmc(k);
        end
 end
ypr=inv(zpr);
format short;
Ybus=A'*ypr*A
```

Exercise:

1. Form the Ybus for the data given

```
     %Slno. fb  tb  z    m    zm
D= [  1     1   2   j0.6  -    -
      2     1   3   j0.5  1    j0.1
      3     3   4   j0.5  -    -
      4     1   2   j0.4  1    j0.2
      5     2   4   j0.2  -    -   ]
```

.

Calculations:

Results:

Inference:

EXPERIMENT 3

Load Flow Analysis using MATLAB

Aim: Load Flow Analysis by Gauss-Siedel method for both PQ and PV buses using MATLAB.

Bus Data:

Bus	Type	V	G_{MW}	G_{MVAR}	L_{MW}	L_{MVAR}	Q_{min}	Q_{max}
1	1	1	0	0	0	0	0	0
2	2	1.02	0.8	0	0	0	0.1	0.8
3	3	1	0	0	1.0	0.8	0	0

Ybus = [-9i 5i 4i
5i -9i 4i
4i 4i -8i]

Algorithm:

1. Read Ybus, number of buses (nbus),Assume bus 1 as slack bus)
   No. of PQ buses (N_{pq}), No. of PV buses (N_{pv})
   Voltage at slack bus (V_i)
   Real power (P) and reactive power (Q) at all pq buses
   Real power (P) and specified voltage (V_{sp}) and Qlimits (Q_{min} and Q_{max}) at PV buses.
   Convergence criteria (ε).
2. Set iteration count k = 1.
3. Calculate voltages at all the PQ buses (p = 2 to N_{pq} + 1), using,

$$V_p^k = \frac{1}{Y_{pp}}\left[\frac{P_p - Q_p}{V_p^*} - \sum_{q}^{p-1} Y_{pq}V_q^{k-1} - \sum_{p+1}^{nbus} Y_{pq}V_q^k\right]$$

4. To calculate voltages at all the PV buses (p = Npq + 2 to nbus)

   Find $QC_p = -\mathrm{Im}\left(V_p^* I_p\right)$ where, $I_p = \sum_{1}^{nbus} Y_{pq}V_q$

5. If QC_p is within Q_{min} and Q_{max}, treat the bus p as PV bus and calculate

$$V_p^k = \frac{1}{Y_{pp}}\left[\frac{P_p - Q_p}{V_p^*} - \sum_{q}^{p-1} Y_{pq}V_q^{k-1} - \sum_{p+1}^{nbus} Y_{pq}V_q^k\right] \quad \text{where, } V_p = |V_{sp}|$$

   at an angle θ_p corresponding to previous iteration.
   Else if QC_p violates Q_{min}, treat bus p as PQ bus and if $QC_p < Q_{min}$, set $Q_p = Q_{min}$ else set $Q_p = Q_{max}$ and find

$$V_p^k = \frac{1}{Y_{pp}}\left[\frac{P_p - Q_p}{V_p^*} - \sum_{q}^{p-1} Y_{pq}V_q^{k-1} - \sum_{p+1}^{nbus} Y_{pq}V_q^k\right]$$

6. Display voltages at all buses and QC_p at PV buses
7. Determine the largest absolute value of $\Delta V = |\Delta V|_{\max} = \left|V_p^k - V_p^{k-1}\right|$.
8. If $|\Delta V|_{max}$ <= *acc* go to next step otherwise set k = k + 1 and go to step no. 3.
9. Stop

Program:

```
ybus=[-9i    5i      4i
       5i   -9i      4i
       4i    4i     -8i];

%              Bus  Type   V     Ang   GMW   GMVAR   LMW  LMVAR   QMin   QMax
     busdata=[1     1      1      0     0     0       0     0       0      0
              2     2      1.02   0     0.8   0       0     0       0.1    0.8
              3     3      1      0     0     0       1.0   0.8     0      0];
bus=busdata(:,1);
type=busdata(:,2);
V=busdata(:,3);
th=busdata(:,4);
GMW=busdata(:,5);
GMVAR=busdata(:,6);
LMW=busdata(:,7);
LMVAR=busdata(:,8);
Qmin=busdata(:,9);
Qmax=busdata(:,10);
nbus=max(bus);
P=GMW-LMW;
Q=GMVAR-LMVAR;
Vprev=V;
toler=1;
k=1;

while(toler>0.001)
   for p=2:nbus
     sumyv=0;
     for q=1:nbus
        if p~=q
           sumyv=sumyv+ybus(p,q)*V(q);
        end
     end
     if type(p)==2
        Q(p)=-imag(conj(V(p))*(sumyv+ybus(p,p)*V(p)));
        if(Q(p)>Qmax(p)||Q(p)<Qmin(p))
           if Q(p)<Qmin(p)
              Q(p)=Qmin(p);
           else
              Q(p)=Qmax(p);
           end
           type(p)=3;
        end
     end

     V(p)=(1/ybus(p,p))*((P(p)-j*Q(p))/conj(V(p))-sumyv);
```

```
        if type(p)==2
            realv(p)=abs(Vprev(p))*cos(angle(V(p)));
            imagv(p)=abs(Vprev(p))*sin(angle(V(p)));
            V(p)=complex(realv(p),imagv(p));
        end
%To find the votages at all buses and Q at pv busses

         fprintf('\n The votages at all buses and Q at pv busses after iteration no  %d' ,k);
         if type(p)==3
             fprintf('\n V(%d)=%.4f at %.2fdeg', p, abs(V(p)), angle(V(p))*180/pi);
         else
           fprintf('\n V(%d)=%.4f at %.2fdeg , Q(%d)= %+.3f\n' , p, abs(V(p)) ,angle(V(p))*180/pi ,
           p,  Q(p));
         end
     end
     k=k+1;
     toler=max(abs(abs(V)-abs(Vprev)));
     Vprev=V;
 end
```

Exercise:

1. Repeat the above problem with limits on Q removed
2. Obtain the voltages at all the buses using GS method for the power system with the following data

Line data

SB	EB	R(pu)	X(pu)
1	2	0.10	0.40
1	4	0.15	0.60
1	5	0.05	0.20
2	3	0.05	0.20
2	4	0.10	0.40
3	5	0.05	0.20

Bus data

Bus No.	P_G (pu)	Q_G (pu)	P_D (pu)	Q_D (pu)	V_{SP} (pu)	Remarks
1	-	-	-	-	1.02	slack
2	-	-	0.60	0.30	-	PQ
3	1.0	-	-	-	1.04	PV
4	-	-	0.40	0.10	-	PQ
5	-	-	0.60	0.20	-	PQ

No Q-limits are specified.

3. Obtain the load flow result for standard IEEE 14-bus system

Calculations:

Results:

Inference:

EXPERIMENT 4

Load Flow Analysis using MiPower

Aim: Load flow analysis using Gauss-Siedel, Newton-Raphson & Fast Decoupledmethods for both PQ and PV buses, using MiPower software package for the given Line and Bus data.

Line and Bus Data:

Line data

Line No.	Bus P	Code Q	Line parameters		
			R pu	X pu	B/2 pu
1	5	4	0.02	0.06	0.03
2	5	1	0.08	0.24	0.025
3	4	1	0.06	0.18	0.02
4	4	2	0.06	0.18	0.02
5	4	3	0.04	0.12	0.015
6	1	2	0.01	0.03	0.01
7	2	3	0.08	0.24	0.025

Bus data

Bus No.	Bus Voltages		Generation		Load		Type of bus
	Magnitude	Phase Angle	Real	Reactive	Real	Reactive	
1	-	-	0	0	0.45	0.15	PQ
2	-	-	0	0	0.4	0.05	PQ
3	-	-	0	0	0.6	0.1	PQ
4	1.0476	-	0.4		0.2	0.1	PV
5	1.06	00	-	-	-	-	slack

Procedure:

To create database configuration:

1) Open Power System Network Editor. Select menu option Database → Configure.
2) Click Browse button, enter desired directory and specify the name of the database to be associated with the single line diagram. Click open button after entering the desired database name. Configure Database dialog will appear with path chosen. Click OK button on the Configure database dialog.
3) Uncheck the Power System Libraries and Standard Relay Libraries. For this example these standard libraries are not needed, because all the data is given on Pu for power system libraries.
4) Click Electrical Information tab. Since the impedances are given on 100 MVA base, check the pu status. Enter the Base MVA and Base frequency.
5) Click OK button to create the database to return to Network Editor.
6) In the network editor, configure the base voltages for the single line diagram. Select menu option Configure→Base voltage. If necessary change the Base-voltages, color, Bus width and click OK.

To draw First Element – Bus:

7) Click on Bus icon provided on power system tool bar. Draw a bus and a dialog appears prompting to give the Bus ID and Bus Name. Click OK. Database manager with corresponding Bus Data form will appear. Click save button. Follow the same procedure for the remaining buses.

To draw Transmission Line:

8) Click on Transmission Line icon provided on power system toolbar. To draw the line click in between two buses and to connect to the from bus double clicking LMB (Left Mouse Button) on the From Bus and join it to another bus by double clicking the mouse button on the To Bus. Element ID dialog will appear.
9) Enter Element ID number and click OK. Database manager with corresponding Line\Cable Data form will be open. Enter Structure Ref Number and click on Transmission Line Library button.
10) Line & Cable Library form will appear. Enter Transmission line library data. After entering data Save and Close. Line\Cable Data form will appear. Click Save, which invokes Network Editor to update next element. Data for remaining elements to be entered in the same way.

To draw Generator:

11) Click on Generator icon provided on power system tool bar. Connect it to bus 1 by clicking the LMB on Bus 1. The Element ID dialog will appear. Enter ID number and click OK. Database with corresponding Generator Data form will appear. Enter all the required details.
12) If the bus is a PV bus (like bus 2), then scheduled power, specified voltage, minimum and maximum real and reactive power data is must.
13) Enter Manufacturer Ref. No. and click on Generator Library button. Generator library form will appear.
14) After entering data Save and close. In Generator Data form click Save. Network Editor Screen will be invoked. Similarly connect all the generators.

To Enter Load Data:

15) Click on Load icon provided on power system tool bar. Connect load by clicking the LMB on Bus. Element ID dialog will appear. Give ID No. and say OK. Load Data form will appear. Enter load details i.e, MW and MVAR and click on power factor. Then click save button, which invokes Network Editor. Same way furnish all the load details.

Solve Load Flow Analysis:

16) Select Menu option Solve→Load Flow Analysis.
17) Click Study Info button and select LFA method for example, Gauss-Siedel Method and enter acceleration factor as 1.4 and P-Tolerance and Q-Tolerance as 0.0001. Click OK.
18) Execute load flow analysis and click on Report in load flow analysis dialog to view report. Repeat the procedure with P and Q tolerances as 0.01 for Newton Raphson Method.

To plot the results on the Single Line Diagram:

19) Select Menu option Plot→Load Flow Analysis. Tick on summary. Select voltage units in required format.

Voltages after Load Flow Studies:

$V_1 = 1.024532$	$\delta_1 = -0.08729$ rad
$V_2 = 1.02394$	$\delta_2 = -0.931$ rad
$V_3 = 1.01825$	$\delta_3 = -0.1074$ rad
$V_4 = 1.0476$	$\delta_4 = -0.049$ rad
$V_5 = 1.06$	$\delta_5 = -0.0$ rad

Calculations:

Results:

Inference:

EXPERIMENT 5

Load Flow Analysis using ETAP

Aim: Load flow analysis using Gauss-Siedel, Newton-Raphson & Fast Decoupled methods for both PQ and PV buses, using ETAP software package for the given Line and Bus data.

Line and Bus Data:

Line data

Line No.	Bus P	Bus q	Line parameters		
			R pu	X pu	B/2 pu
1	5	4	0.02	0.06	0.03
2	5	1	0.08	0.24	0.025
3	4	1	0.06	0.18	0.02
4	4	2	0.06	0.18	0.02
5	4	3	0.04	0.12	0.015
6	1	2	0.01	0.03	0.01
7	2	3	0.08	0.24	0.025

Bus data

Bus No.	Bus Voltages		Generation		Load		Type of bus
	Magnitude	Phase Angle	Real	Reactive	Real	Reactive	
1	-	-	0	0	0.45	0.15	PQ
2	-	-	0	0	0.4	0.05	PQ
3	-	-	0	0	0.6	0.1	PQ
4	1.0476	-	0.4		0.2	0.1	PV
5	1.06	00	-	-	-	-	slack

Procedure:

1) For PQ Bus: Select bus from the power system toolbar. Enter the nominal kV as 10 for the bus. Enter the initial voltage as 100%, angle as 0 degress.
2) In Phase V tab, ensure that all voltages are at 100% voltage. Click on OK.
3) For PV Bus: In this also, nominal kV will be 10 itself. Do not multiply it with 1.0476pu given in the problem. However, the initial voltage will be 104.76% and angle 0 degrees (the value given in data).
4) In Phase V tab, ensure that all voltages are at 104.76%.
5) For Slack Bus: For as slack bus, keep nominal kV as 10 itself. However in the initial voltage, give 106% (the value given in data) and angle as zero.

6) In Phase V tab, ensure that all voltages are at 106%.

7) For load data: Connect the static load to the desired bus and ensure that the bus number and corresponding voltage is correct.

8) In 'Loading' tab, enter the MW and MVAr data. The MVA will automatically be calculated. The same should also reflect in 'Loading' table under 'design'. Now enter the operating load equal to the MW and MVAr given. The kV rating should be 10, regardless of the bus type. Click on OK. Repeat the procedure for all loads.

9) For Generator data: In generator, check the bus number and also select the type of bus. For PV generator, select voltage control as the operating mode.

10) The kV rating will still be 10kV even though the bus is a PV bus.

11) In 'design' table, enter %V as 104.76, MW as 40 and Qmax as the given value (if it is not given the you must calculate).

12) Enter the %V as 104.76, angle as zero, MW and MVAr at the bottom under 'operating value'.

13) Select the operating mode as 'Swing'.

14) In Rating tab, enter the MW as an arbitrary high value, keep the kV as 10 itself.

15) In design tabular column, enter the % voltage as 106% (value given in data). In the diagram below it says 100%, but you should enter 106% itself and not 100%.

16) Connect the transmission line and check for the bus numbers.

17) In the parameters tab, click on conductor library. In conductor library window, select AAC conductor and click on OK. Now the AAC parameters will be reflected as phase conductor values.

18) Enter RT1 as the R given in data, and Xa as the X given in data. At present do not change Xa'.

19) Click on configuration tab and enter the height and spacing of conductors.

20) In impedance tab, select 'user-defined' and 'ohms', and enter RT1 and X from the data, retain RT2 as it is. Note that the Y it asks is in microsiemens. That means you should multiply the given B/2 by 106 and then enter the high value in Y. Do not multiply by 2.

21) Change the temperature range as 20 each.

22) Now go back to 'parameter' tab. The Xa' (capacitive reactance) is required in megohms. So obtain X = 1/Y, and then multiply by 10-6. The value is so low that ETAP considers it as zero. Hence enter Xa' as zero.

23) To start load flow, click on 'Load Flow' icon.

24) Click on 'Edit Study Case' option (it has a briefcase symbol). This option may be directly visible, or it may be hidden. If it is not directly visible, click the downward pointing arrow on the right top corner. Even now if it is not visible, check in 'view' if 'study case toolbar' has been enabled. Select the appropriate method, click on OK.

25) Now click on 'Run Load Flow' option to obtain the output. To obtain report, click on report manager, click on complete, select PDF and click OK.

Calculations:

Results:

Inference:

EXPERIMENT 6

Determination of Bus currents, Bus power and Line flows using MATLAB

Aim: Determine the Bus currents, Bus power and Line flows for the given system using MATLAB.

Algorithm:

1. Read the following line data at each line from bus no(p), to bus no(q), line impedance(Zpq) and half line charging admittance(Ychpq) Read voltages at all buses
2. Convert line impedance to admittance of each line Ypq
3. Repeat step i to x for K=1 to no. of lines
   i. p = from bus no   q = to bus no
   ii. Line current, Ipq = (Vp-Vq)Ypq + Vp * Ychpq
   iii. Bus current IIp=IIp+Ipq
   iv. Line flow, SLpq =Vp * Ipq^*
   v. Generation at bus p, SGp = SGp + SLpq
   vi. Line current, Iqp = (Vq-Vp)Ypq + Vq*Ychqp
   vii. Bus current, IIq = IIq + Iqp
   viii. Line flow, SLqp = Vq * Iqp^*
   ix. Loss of line k, Loss k= SLpq + SLqp
   x. Total loss = Total loss + Loss k
4. Display current at each bus
   Display line flows and line loss at each line
   Display generations at each bus
   Display the total losses
5. Stop

Program:

```
%      p   q           z            hlc(ADM)

D=   [5    4     0.02+0.06i     0.03i
       5    1    0.08+0.24i     0.025i
       4    1    0.06+0.18i     0.02i
       4    2    0.06+0.18i     0.02i
       4    3    0.04+0.12i     0.015i
       1    2    0.01+0.03i     0.01i
       2    3    0.08+0.24i     0.025i];

v(1)=1+0.2i;    v(2)=1.01-0.5i;    v(3)=1.05-0.3i;    v(4)=1.01-0.5i;    v(5)=1.0-0i;
fb=D(:,1);
tb=D(:,2);
Z=D(:,3);
ysh=D(:,4);
 y=1./Z;
nbus=max(max(fb),max(tb));
nline=length(fb);
II=zeros(nbus,1);
SG=zeros(nbus,1);
totloss=0;
```

```
for k=1:nline
    p=fb(k);q=tb(k);
    I(p,q)=(v(p)-v(q))*y(k)+v(p)*ysh(k);
    II(p)=II(p)+I(p,q);
    SL(p,q)=v(p)*conj(I(p,q));
    SG(p)=SG(p)+SL(p,q);
    I(q,p)=(v(q)-v(p))*y(k)+v(q)*ysh(k);
    II(q)=II(q)+I(q,p);
    SL(q,p)=v(q)*conj(I(q,p));
    SG(q)=SG(q)+SL(q,p);
   loss(k)=SL(p,q)+SL(q,p);
   totloss=totloss+loss(k);
end
fprintf('bus currents');
fprintf('\nBus no          Current');
for k=1:nbus
        fprintf('\n   %d     %10.4f %+10.4fi',k,real(II(k)),imag(II(k)));
end
fprintf('\nLine flows');
fprintf('\nFrom bus  To bus         Lineflows               Line Loss');
for k=1:nline
        p=fb(k);
        q=tb(k);
 fprintf('\n   %d       %d      %10.4f%+10.4fi %10.4f%+10.4fi', p,q, real(SL(p,q)) ,imag(SL(p,q)) ,
              real(loss(k)) ,imag(loss(k)));

fprintf('\n    %d       %d       %10.4f%+10.4fi  %10.4f%+10.4fi',q,p  ,real(SL(q,p))  ,imag(SL(q,p)),
              real(loss(k)),imag(loss(k)));

end
fprintf('\nBus Generations');
fprintf('\nBus no        Generation');
for k=1:nbus
        fprintf('\n%d      %10.4f%+10.4fi',k,real(SG(k)),imag(SG(k)));
 end
fprintf('\n\nTotal Losses=%10.4f%+10.4fi',real(totloss),imag(totloss));
```

<u>Excercise</u>

1. Obtain the line flows for the following data:

   The system has three lines connected between 1-2, 1-3 and 2-3. Each line has a series impedance of 0.02+j0.08 pu, total shunt admittance of j0.02pu. The specified quantities of the buses are tabulated in the next page on 100MVA base.

Bus	**Real Load demand P_D**	**Reactive Load demand Q_D**	**Real PowerGen P_G**	**Reactive Power Gen Q_G**	**Voltage Specification**
1	2pu	1 pu	Unspecified	Unspecified	$1.04 \angle 0^0$ Slack
2	0	0	0.5	1	PQ bus
3	1.5pu	0.6 pu	0	QG3	1.04 (PV)

The voltages at the various buses are:

$V_1 = 1.04\angle 0^0$pu, $V_2 = 1.0819\angle -1.38^0$pu, $V_3 = 1.04 \angle -3.75^0$pu

Calculations:

Results:

Inference:

EXPERIMENT 7

Short circuit studies using MiPower

Aim: **To conduct short circuit studies for the given network using MiPower software package and determine the fault current and MVA for both symmetrical and unsymmetrical faults.**

PS Data:

The Transmission linedata is given below.

Bus – code	Impedance Zpq	Line charging
p-q	**Zpq**	**Y'pq/2**
3 – 4	0.00 + j0.15	0
3 – 5	0.00 + j0.10	0
3 – 6	0.00 + j0.20	0
5 – 6	0.00 + j0.15	0
4 – 6	0.00 + j0.10	0

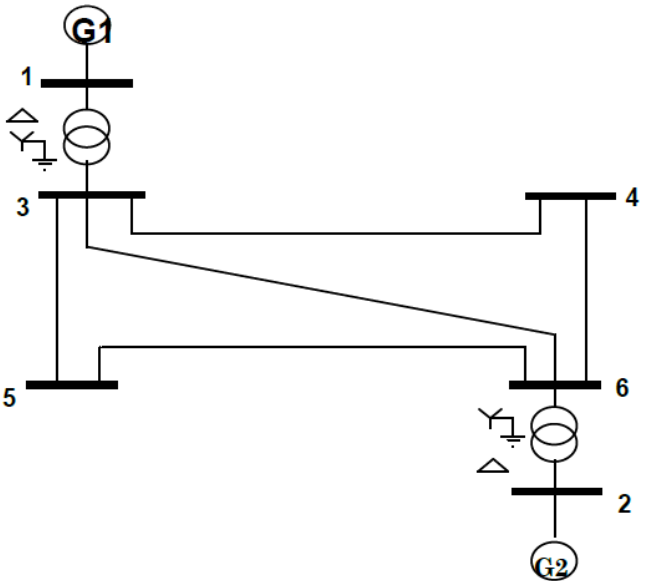
Generator details

MVA Rating of G1 & G2 = 100 MVA, 11 kV with X'_d = 10 %

Transformer details

KV Rating of T1 & T2 = 11/110 kV, 100 MVA, leakage reactance x = 5 %

***** All impedances are on 100 MVA base***



Procedure:

Note: Procedure remains same as LFA in Mipower, only solve scenario will change.

To draw Transformer:

- Click on Two Winding Transformer icon provided on power system tool bar. To draw the transformer click in between two buses and to connect to the from bus, double click LMB (Left Mouse Button) on the From Bus and join it to another bus by double clicking the mouse button on the To Bus. Element ID dialog will appear. Click OK.
- Transformer Element Data form will be open. Enter the Manufacturer Ref. Number. Enter transformer data. Click on Transformer Library >>button. Enter the required data and save and close library screen.
- Transformer element data form will appear. Click Save button, which invokes network editor. In the similar way enter other transformer details.

Solve short circuit studies

- Choose menu option Solve Short Circuit Analysis or click on SCS button on the toolbar on the right side of the screen. Short circuit analysis screen appears.
- In study info- under short circuit data, select the type of fault and check the fault on bus and choose the faulted bus.
- In Short Circuit Output Options select detail data and results to plot graph.
- Afterwards click Execute. Short circuit study will be executed. Click on Report to view the report file.

Calculations:

Results:

Inference:

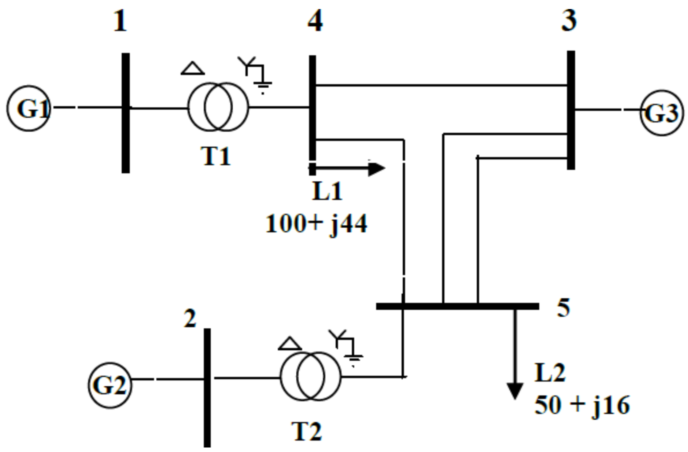
EXPERIMENT 8

Transient Stability Studies

Aim: To simulate Transient Stability Studies using MiPower software package for the given system and plot the transient behavior of the machine.

PS Data: Single line diagram of a 5-bus system with three generating units, four lines and two transformers and two loads are shown below. Per-unit transmission line series impedances and shunt susceptances are given on 100 MVA base, generator's transient impedance and transformer leakage reactances are given in the accompanying table.

Values given are on 100 MVA Base. Frequency = 50 Hz



If a 3 - phase fault occurs on line 4 - 5 near bus 4 and the fault is cleared by simultaneously opening the circuit breaker at the ends of the line 4-5 at 0.225 seconds (fault clearing time), plot the swing curve and comment on stability of machine 1 and machine 2

Transmission Line Details		
Bus – code	**Impedance**	**Line charging**
p-q	**Zpq**	**Y'pq/2**
3 - 4	0.007 + j0.04	j0.041
3 -5(1)	0.008 + j0.047	j0.049
3 -5 (2)	0.008 + j0.047	j0.049
4 - 5	0.018 + j0.110	j0.113

Transformer Details:

T1 = 20/230 kV 400 MVA with Leakage reactance = 0.022 pu

T2 = 18/230 kV 250 MVA with Leakage reactance = 0.040 pu

Generator Details:

G1 = 400 MVA, 20 kV, X'd = 0.067 pu, H = 11.2 MJ / MVA

G2 = 250 MVA, 18 kV, X'd = 0.10 pu, H = 8.0 MJ / MVA

G3 = 1000 MVA, 230 kV, X'd = 0.00001 pu, H = 1000 MJ / MVA (Infinite Bus Modelling)

Generation and Load Details					
Bus Code 'p'	**Generation**		**Load**		**Specified Voltage**
	MW	**Mvar**	**MW**	**Mvar**	
1	350	71.2	0	0	1.03
2	185	29.8	0	0	1.02
3	800	0	0	0	1.0
4	0	0	100	44	Unknown
5	0	0	50	16	Unknown

Procedure:

Note: Procedure remains same as LFA in Mipower, only solve scenario will change.

- After data configuration and single line diagram run Load flow analysis. Only if LFA is correct then solve for transient stability analysis
- Click on Solve Transient stability analysis. On Transient Stability Studies screen click on Study Info….button.
- Select swing bus, type of disturbance and buses of interest. To simulate 3 phase to ground fault, select the Disturbances as Three Phase To Ground Fault from the disturbance list and click on Disturbance Info button to enter the fault data.
- Fault is on bus 4 so select bus 4 from the Bus number list box. Click OK to return to previous form.
- To account the effect of opening of breaker, in the disturbance list select Change in transmission Line Parameters and click on Disturbance Info button.
- In this, select line between bus 4 and bus 5. Give disturbance starting time as 0.225 secs and make positive sequence resistance as zero and reactance very high accounting for opening of the line (let us say 9999).
- Finally you will return to the previous dialog. Here list of disturbances applied on the network are listed as shown below. Click OK button to return to Solve dialog. On the Solve dialog box, click Execute button to execute transient stability study.
- **Results Observation:** The results can be observed by clicking Report button. The results can be best analysed using graph. For this click on Graph button.
- Graph editor will open the corresponding plot file of the study. Window 1 is used for displaying the graphs and window 2 holds the plot variables like time in seconds, swing curve of machines, machine internal angle, machine voltage, machine current etc. User has to choose plot variables in the 2nd window.

Calculations:

Results:

Inference:

EXPERIMENT 9

Swing curve using Euler's Method

Aim: To plot swing curve for the given system using Euler's Method in MATLAB.

Data:
Pmax1=1.714 pu
Pmax2=0.63 pu
Pmax3=1.333 pu
Power transferred =0.8 pu
Fault clearing time =0.125 secs
Frequency=50 Hz

Algorithm

1.Read maximum power before fault, during fault and post fault
2. Read the power transferred and the clearing time
3.Read H and frequency
4.Calculate initial value of δ. Initial ω is zero.
5.Calculate derivatives and intermediate values using following equations

$$D_1 = \omega_o$$

$$D_2 = \frac{P_m - P_{\max}\sin\delta_0}{M}$$

$$\delta^P = \delta_0 + D_1\Delta t$$

$$\omega^P = \omega_0 + D_2\Delta t$$

$$D_{1P} = \omega^P$$

$$D_{2P} = \frac{P_m - P_{\max}\sin\delta^P}{M}$$

6. Update δ and ω

$$\delta_1 = \delta_0 + \left(\frac{D_1 + D_{1P}}{2}\right)\Delta t$$

$$\omega_1 = \omega_0 + \left(\frac{D_2 + D_{2P}}{2}\right)\Delta t$$

7.Continue for the required time of simulation

Program

```
clear
pmax1=input('enter the maximum power before fault\n');
pmax2=input('enter the maximum power during fault\n');
pmax3=input('enter the maximum power after fault\n');
power=input('enter the value of power transferred\n')
tcl=input('enter clearing time\n')
H=input('enter value of interial constant H\n') freq=input('enter frequency\n')
delta0=asin(power/pmax1);    % Initial angle depends on pre-fault maximum power
```

```
omega0=0.0;
M=H/(pi*freq);
delta_t=0.01;                    % Time step. Change the value to test for different time steps
pmax=pmax2; % At t=0, fault occurs and hence we start with the maximum power during
fault y1=[];
z1=[];
for t=0.0:delta_t:0.5
if(t>tcl)
   pmax=pmax3; % If time is greater than fault clearing time, use post-fault maximum power
end
D1=omega0;
D2=(power-pmax*sin(delta0))/M;
delp=delta0+D1*delta_t;                    % Intermediate values of delta and omega
omegp=omega0+D2*delta_t;
D1p=omegp;
D2p=(power-pmax*sin(delp))/M; delta0=delta0+(D1+D1p)/2*delta_t; omega0=omega0+
(D2+D2p)/2*delta_t;
delta=delta0*180/pi;                        % Convert to delta to degrees
omega=omega0;
y=[t D1 D2 D1p D2p ];                       % to display values of time and derivatives
z=[t pmax delta omega];
 y1=[y1;y];
z1=[z1;z];
plot(t,delta,'r')
hold on
end
disp(y1)
disp(z1)
```

Exercise

1.Simulate for sustained fault and determine critical clearing time graphically

Calculations:

Results:

Inference:

EXPERIMENT 10

Solution of Swing curve using Runge-Kutta method

Aim: To plot swing curve for the given system using Runge-Kutta method in MATLAB.

Data

Pmax1=1.714 pu

Pmax2=0.63 pu

Pmax3=1.333 pu

Power transferred =0.8 pu

Fault clearing time =0.125 secs

Frequency=50 Hz

Assume fault occurs at t=0 secs. The data consistsof the maximum power transfers pre-fault, during fault and post-fault, along with system data. **Sustained fault is simply simulated by giving a large fault clearing time.** Values of power are in pu.

Algorithm :

1. Read maximum power before fault, during fault and post fault
2. Read the power transferred and the clearing time
3. Read H and frequency
4. Calculate initial value of δ. Initial ω is zero.
5. The two first order differential equations to be solved to obtain solution for the swingequation are:

$$\frac{d\delta}{dt} = \omega$$

$$\frac{d\omega}{dt} = \frac{P_a}{M} = \frac{P_m - P_{max}\sin\delta}{M}$$

Starting from initial value δ_0, ω_0, t_0 and a step size of Δt the formulae are as follows

$$k_1 = \omega_0 \Delta t$$

$$l_1 = \left[\frac{P_m - P_{max}\sin\delta_0}{M}\right]\Delta t$$

$$k_2 = \left(\omega_0 + \frac{l_1}{2}\right)\Delta t$$

$$l_2 = \left[\frac{P_m - P_{max}\sin\left(\delta_0 + \frac{k_1}{2}\right)}{M}\right]\Delta t$$

$$k_3 = \left(\omega_0 + \frac{l_2}{2}\right)\Delta t$$

$$l_3 = \left[\frac{P_m - P_{max}\sin\left(\delta_0 + \frac{k_2}{2}\right)}{M}\right]\Delta t$$

$$k_4 = (\omega_0 + l_3)\Delta t$$

$$l_4 = \left[\frac{P_m - P_{max}\sin(\delta_0 + k_3)}{M}\right]\Delta t$$

$$\delta_1 = \delta_0 + \frac{1}{6}\left[k_1 + 2k_2 + 2k_3 + k_4\right]$$

$$\omega_1 = \omega_0 + \frac{1}{6}\left[l_1 + 2l_2 + 2l_3 + l_4\right]$$

Program

```
Clear
pmax1=input('enter the maximum power before fault\n');
pmax2=input('enter the maximum power during fault\n');
pmax3=input('enter the maximum power after fault\n');
power=input('enter the value of power transferred\n') tcl=input('enter clearing time\n')
H=input('enter value of interial constant H\n')
freq=input('enterfrequency\n')
delta0=asin(power/pmax1);
omega0=0.0;
M=H/(pi*freq);
delta_t=0.05;
pmax=pmax2;
y1=[];
 z1=[];
for t=0.0:delta_t:0.5 if(t>tcl)
    pmax=pmax3;
end
k1=omega0*delta_t;                                    % Calculate the coefficients
l1=(power-pmax*sin(delta0))/M*delta_t;
k2=(omega0+l1/2)*delta_t;
l2=(power-pmax*sin(delta0+k1/2))/M*delta_t;
k3=(omega0+l2/2)*delta_t;
l3=(power-pmax*sin(delta0+k2/2))/M*delta_t;
k4=(omega0+l3)*delta_t;
l4=(power-pmax*sin(delta0+k3))/M*delta_t;
delta0=delta0+(k1+2*k2+2*k3+k4)/6;
omega0=omega0+(l1+2*l2+2*l3+l4)/6;
delta=delta0*180/pi;
omega=omega0;
y=[t k1 l1 k2 l2 k3 l3 k4 l4 ];
z=[t pmax delta omega]; y1=[y1;y];
z1=[z1;z];
plot(t,delta,'*-r')
hold on
end
disp(y1)
disp(z1)
```

Exercise

1. Execute the program for step size of 0.001 s.
2. Simulate a sustained fault
3. Determine critical clearing time from direct simulation

Calculations:

Results:

Inference:

EXPERIMENT 11

Economic Load Dispatch

Aim: a) To determine economic load dispatch without losses including generator limits in MATLAB.

The inputis given through a file eco_wol_genlit_in. The cost function is given by

$F_i=a_i+b_iP_{Gi}+c_iP_{Gi}^2$.

Cost coeffecients are read in a matrix in the order c_i, b_i, a_i for each generator in a line.

Algorithm

1. Read cost coefficients, Power demand, Initial lambda and generator limits from file.
2. Start iteration count = 1
3. Calculate generator powers using

$$P_{Gi}=\frac{\lambda-b_i}{2c_i}$$

4. Check for violations of any generator limits. If any limit is violated peg generation at the limit.
5. Calculate $\Delta P = P_D - (\text{sum of } P_{Gi})$
6. If ΔP is less than tolerance stop. Else calculate change in λ in any iteration using

$$\Delta\lambda^{(r)}=\frac{\Delta P^{(r)}}{\sum_{i=1}^{n_g}\frac{1}{2c_i}}$$

7. Update $\lambda^{r+1}=\lambda^{(r)}+\Delta\lambda^{(r)}$
8. Increment iteration count and go to step 3.

Program

```
clear;
diary('wer.txt')
y1=[];
[cost_coeff,PD,Ini_lam,gen_lim]=eco_wol_genlit_in;         %Read input from file
Delp=100;
n=length(cost_coeff(:,1));                                  %Get number of generators
lam=Ini_lam;                                                      %Initial value of Lambda
while(abs(Delp)>0.001)
   iter=iter+1;                                             %Update iteration count
 for i=1:n
      P(i)=(lam-cost_coeff(i,2))/(2*cost_coeff(i,1));       %Compute PGi
 end
 for i=1:n
         if (P(i)<gen_lim(i,1))                        % Check for generator limit violations
            P(i)=gen_lim(i,1);

        end

        if (P(i)>gen_lim(i,2))
```

```
            P(i)=gen_lim(i,2);
        end
    end
    Ptotal=sum(P);                              %Total generation
    Delp=PD-Ptotal;                             %Demand - Generation
   sigma_a=sum(1./(2.*cost_coeff(:,1)));
    lam=lam+Delp/sigma_a;                       %Update Lambda
    y=[iter P Ptotal Delp lam];
    y1=[y1;y];
   end
   disp(y1)
   diary('wer.txt')
```

Data file

```
function[cost_coeff,PD,Ini_lam,gen_lim]=eco_wol_genlit_in();
cost_coeff=[0.004 7.2  350
            0.0025 7.3  500
            0.003  6.74 600];
PD=450;
Ini_lam=6.0;
gen_lim=[125 300
         125 300
         125 300];
end
```

<u>Excercise</u>

1. Repeat the problem with different values of initial λ and compare results.
2. Run the program for PD=300 and PD=650
3. Modify program to display cost of generation.
4. Modify program to compare cost of optimal generation with cost of equal generation.

Calculations:

Results:

Inference:

<u>Aim</u>: b) To determine economic load dispatch with losses including generator limits in MATLAB.

The input is given through a file eco_wol_input. The cost function is given by $F_i=a_i+b_iP_{gi}+c_iP_{gi}^2$. Cost coefficients are read in a matrix with c_i, b_i, a_i for each generator in a line **.** The loss (B) coefficients are also read as part of data. The off-diagonal elements of B matrix are neglected.

Algorithm

1. Start with an initial estimate $\lambda^{(r)}$
2. Solve for $P_{Gi}^{(r)}$

$$P_{Gi} = \frac{\lambda - b_i}{2\left(c_i + \lambda B_{ii}\right)}$$

3. Solve for $P_L^{(r)}$ (Loss) using $P_L = [P_G][B][P_G]^T$
4. Compute $\left(\frac{dP_{Gi}}{d\lambda}\right)^{(r)}$ for all i, using

$$\left(\frac{dP_{Gi}}{d\lambda}\right)^{(r)} = \frac{c_i + b_i B_{ii}}{2\left(c_i + \lambda^{(r)} B_{ii}\right)^2}$$

5. Compute $\Delta P^{(r)}$ using

$$\Delta P^{(r)} = P_D + P_L^{(r)} - \sum_{i=1}^{n_g} P_{Gi}^{(r)}$$

6. Compute $\Delta\lambda^{(r)}$ using

$$\Delta\lambda^{(r)} = \frac{\Delta P^{(r)}}{\sum_{i=1}^{n_g}\left(\frac{dP_{Gi}}{d\lambda}\right)^{r}}$$

7. $\lambda^{(r+1)} = \lambda^{(r)} + \Delta\lambda^{(r)}$
8. Go to step 2 till $\Delta P^{(r)} \le \epsilon$

<u>Program</u>

```
clear; diary('wer.txt') y1=[];
[cost_coef,PD,b_coef,lam]=eco_wl_in;         %Read input from file
ci_coef=cost_coef(:,1);
bi_coef=cost_coef(:,2);
cdiag=diag(ci_coef);
iter=0;                                      %Iteration count = 0
Delp=100;
n=length(cost_coef(:,1));                    %Get number of generators
b_coef=b_coef./100                           % Convert B coefficients to MW-1

while(abs(Delp)>0.001)
   iter=iter+1;                              %Update iteration count
   P1=lam-bi_coef;
```

```
for i=1:n
        P2(i)=2*(ci_coef(i)+lam*b_coef(i,i));
        P(i)=P1(i)/P2(i);
end
  Ploss =P*b_coef*P';
for i=1:n
        m1(i)=ci_coef(i)+b_coef(i,i)*bi_coef(i);
        m2(i)=2*(ci_coef(i)+lam*b_coef(i,i))*(ci_coef(i)+lam*b_coef(i,i));
        m(i)=m1(i)/m2(i);
end

Delp=PD+Ploss-sum(P);
Dellam=Delp/sum(m);
lam=lam+Dellam;                                          %Update Lambda
Ptotal=sum(P);
y=[iter P     Ptotal Delp lam];
y1=[y1;y];
end
disp(y1)
disp('Demand')
```

Data file

```
function[cost_coeff,PD,b_coef,lam]=eco_wl_in();
cost_coeff=[0.008 7.0 200
                 0.009 6.3 180
                 0.007 6.8 140];
PD=500;
b_coef=[ 0.0218   0.0        0.0;
             0.0        0.0228   0.0;
             0.0        0.0        0.0179;]
lam=8;
```

Exercise :

1. Obtain optimal schedule for the following data:
The fuel cost of two plants is given by
$F1=200+10.333P_{G1}+0.00889P_{G1}^2$ Rs/h
$F2=240+10.833P_{G2}+0.00741P_{G2}^2$ Rs/h
Determine the economic schedule to meet a demand of 150MW, corresponding cost and loss.
The transmission loss is given by, $Ploss=0.001\ P_{G1}^2 +0.002\ P_{G2}^2$.

Calculations:

Results:

Inference:

EXPERIMENT 12

Fault scenario simulation

Aim: To simulate fault scenario in a feeder and in a transformer/bus using virtual lab

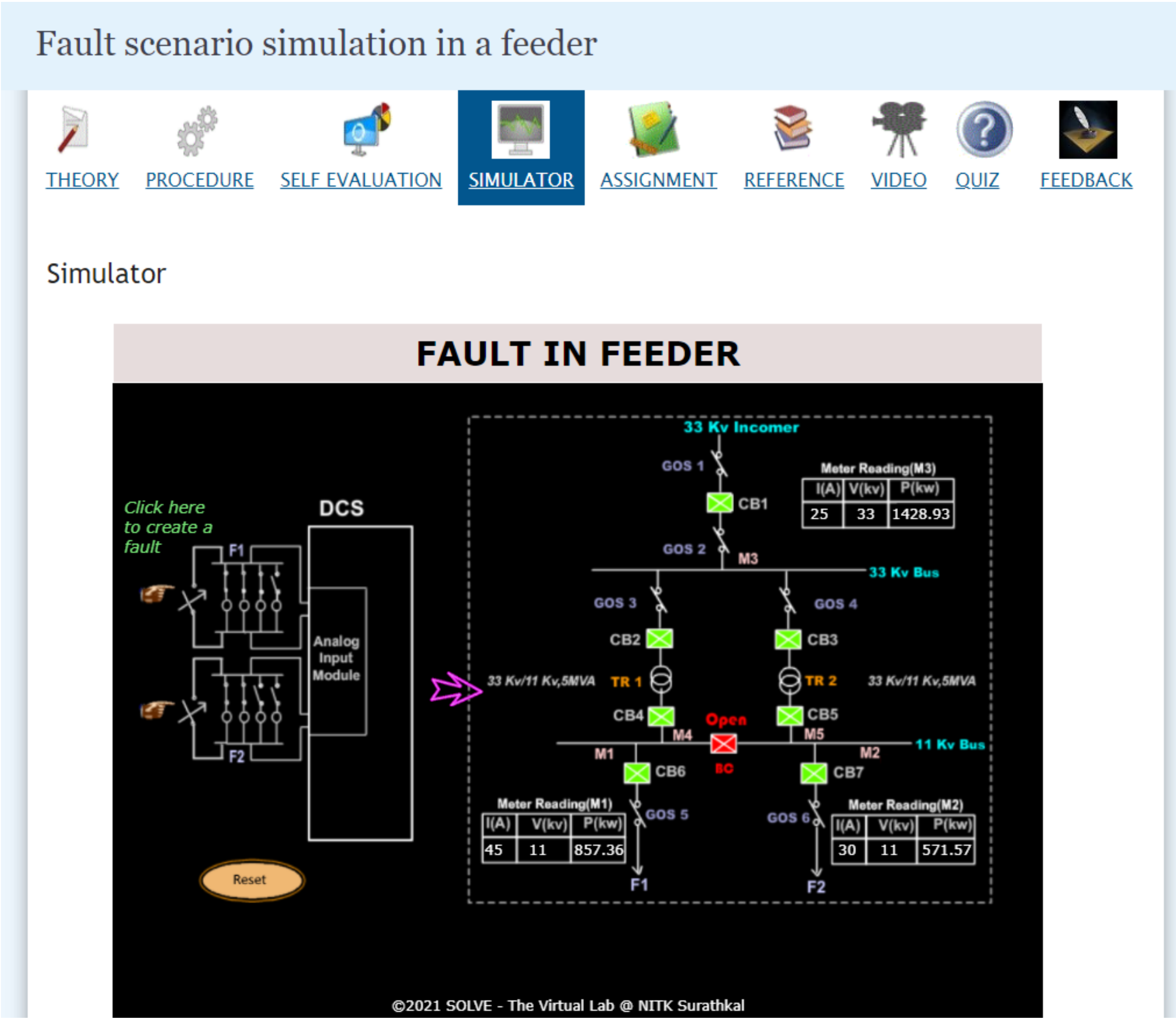
a) Fault scenario simulation in a feeder

Link: https://sa-nitk.vlabs.ac.in/exp/simulation-feeder/procedure.html

Whenever fault happens in a feeder, the circuit breaker placed in the feeder trips due to high fault current. This will alter the loading conditions in the substation. Whenever fault occurs, Alarm will be generated indicating tripping of circuit breaker.

Simulate the following conditions:

- ✓ Study the pre-fault condition.
- ✓ Create the Fault on feeder 1 and feeder 2.
- ✓ Observe the breaker position and generated Alarm.
- ✓ Observe the output i.e, current, voltage and power of both the feeders.



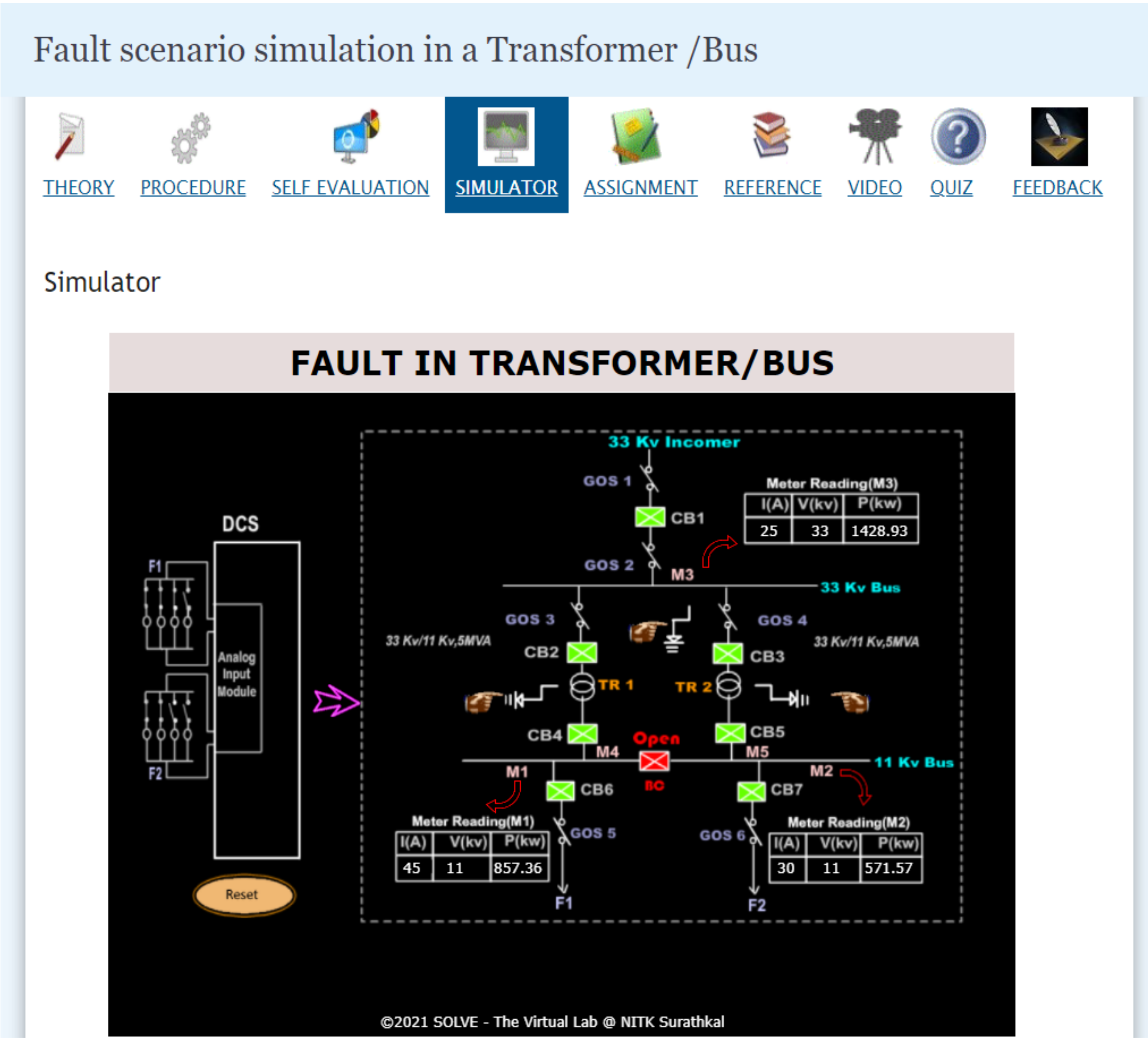
b) Fault scenario simulation in a Transformer /Bus

Link: https://sa-nitk.vlabs.ac.in/exp/simulation-transformer/procedure.html

The occurrence of fault in a Transformer or Bus makes the corresponding circuit breaker to open and depending on configuration, the power to feeder load varies.

Simulate the following conditions:

- ✓ Study the pre-fault condition.
- ✓ Create the Fault on Transformer 1, Transformer 2 and on 33 kV Bus.
- ✓ Observe the respective breaker position.
- ✓ Observe the output i.e, current, voltage and power of all the 3 meters.



Results:

Inference:

LAB Question Bank

Question-1

1. Give the algorithm for determination of bus admittance matrix by direct method.
2. Determine Bus Admittance matrix by direct method for a power system with following data

Line No.	Between buses	Line impedance	Half line charging admittance	Off nominal tap ratio
1	1-4	0.08 + j0.37	0.007	1.0
2	1-6	0.123+j0.518	0.010	1.0
3	2-3	0.723 + j1.05	0.0	1.09
4	2-5	0.282 +j0.64	0.0	1.0
5	4-3	0.0 + j0.133	0.0	1.0
6	4-6	0.097 + j0.407	0.0	0.985
7	6-5	0.0 + j0.3	0.0	1.0

a. Comment on the nature of the Ybus.
b. If a shunt capacitor of susceptance 0.3 pu is added to the above system at bus no 3,how are the elements modified?.
c. If line no 3 is removed, which elements need to be modified? How are theymodified?

Question-2

1. Give algorithm to determine bus admittance matrix using singular transformation.
2. Obtain Ybus using singular transformation for the following data.

Line	R	X	hlc
1-2	0.05	0.15	0.0025
1-3	0.1	0.3	0.03
2-3	0.15	0.45	0.05
2-4	0.10	0.30	0.0
3-4	0.05	0.15	0.0125

3. Determine the bus impedance matrix from Ybus.

Question-3

1. A) Using singular transformation technique, determine Ybus for the given test system usingMATLAB

Elemen tNo.	Self-Impedance		Mutual Impedance	
1	1-2(1)	0.6	-	-
2	1-3	0.5	1-2(1)	0.1
3	3-4	0.5	-	-
4	1-2(2)	0.4	1-2(1)	0.2
5	2-4	0.2	-	-

Consider bus 1 as reference bus

B) Determine line flows and line losses, using MATLAB, for system with following data.

Line No.	Bus P	Code Q	Line Parameters		
			Rpu	X pu	B/2 pu
1	5	4	0.02	0.06	0.03
2	5	1	0.08	0.24	0.025
3	4	1	0.06	0.18	0.02
4	4	2	0.06	0.18	0.02
5	4	3	0.04	0.12	0.015
6	1	2	0.01	0.03	0.01
7	2	3	0.08	0.24	0.025

V1= 1+ 0.2j

V2= 1.01-0.5j

V3= 1.05-0.3j

V4= 1.01-0.5j

V5= 1.0-0.0j

Question-4

1. For the given system form the Ybus. Draw the one line diagram of the system

From	To	X	Type
2	1	0.25	1
3	2	0.10	2
4	2	0.1	2
3	1	0.25	3
3	4	0.1	4

Question-5

1. Draw the flow chart for the GS method of power flow solution.
2. Using the available software package, determine the voltage at all the buses for the datagiven below, using GS method.

Line data

Line No.	Bus P	Code Q	Line parameters		
			R pu	X pu	B/2 pu
1	5	4	0.02	0.06	0.03
2	5	1	0.08	0.24	0.025
3	4	1	0.06	0.18	0.02
4	4	2	0.06	0.18	0.02
5	4	3	0.04	0.12	0.015
6	1	2	0.01	0.03	0.01
7	2	3	0.08	0.24	0.025

Bus data

Bus No.	Bus Voltages		Generation		Load		Type of bus
	Magnitude	Phase Angle	Real	Reactive	Real	Reactive	
1	-	-	0	0	0.45	0.15	PQ
2	-	-	0	0	0.4	0.05	PQ
3	-	-	0	0	0.6	0.1	PQ
4	1.0476	-	0.4	-	0.2	0.1	PV
5	1.06	00	-	-	-	-	slack

a) Comment on effect of acceleration factor on the solution.
b) If Q limits on bus 4 are imposed such that Qmin = 0.0 pu and Qmax= 0.5 pu, what is effect on solution?
c) What is the total loss in the system?
d) What are the line flows?

Question-6

1. Load flow analysis using Gauss-Siedel method for both PQ and PV buses, using Matlab. The system has three lines connected between 1-2,1-3 and 2-3. Each line has a series impedanceof 0.02+j0.08 pu, total shunt admittance of j0.02 pu. The specified quantities of the buses are tabulated below on 100MVA base. Obtain the Bus Voltages.

Bus	**Real Load demand P_D**	**Reactive load demandQ_D**	**Real powerGen P_G**	**Reactive power GenQ_G**	**Voltage Specification**
1	2pu	1 pu	Unspecified	Unspecified	$1.04 \angle 0^0$ slack
2	0	0	0.5	1	PQ bus
3	1.5pu	0.6pu	0	QG3	1.04(PV)

2. In the above system, the scheduled real power at bus 3 is changed to 1.0pu. Determine the newbus voltages and comment on the results.

Question-7

1. Draw the flow chart for the NR method of power flow solution.
2. Using the available software package, determine the voltage at all the buses for the datagiven below, using NR method.

Line data

Line No.	Bus P	Code Q	Line parameters R pu	X pu	B/2 pu
1	5	4	0.02	0.06	0.03
2	5	1	0.08	0.24	0.025
3	4	1	0.06	0.18	0.02
4	4	2	0.06	0.18	0.02
5	4	3	0.04	0.12	0.015
6	1	2	0.01	0.03	0.01
7	2	3	0.08	0.24	0.025

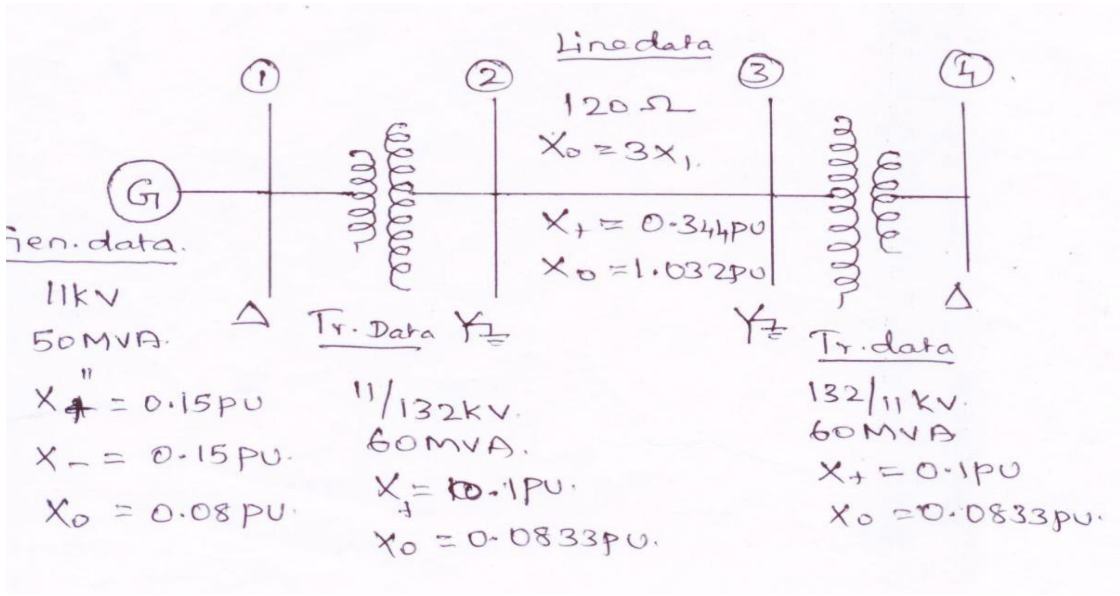
Bus data

Bus No.	Bus Voltages		Generation		Load		Type of bus
	Magnitude	Phase Angle	Real	Reactive	Real	Reactive	
1	-	-	0	0	0.45	0.15	PQ
2	-	-	0	0	0.4	0.05	PQ
3	-	-	0	0	0.6	0.1	PQ
4	1.0476	-	0.4	-	0.2	0.1	PV
5	1.06	00	-	-	-	-	slack

3. Compare the results with FDLF method.
4. If Q limits on bus 4 are imposed such that Qmin = 0.0 pu and Qmax= 0.5 pu, what is effect on solution?
5. What is the total loss in the system?
6. What are the line flows?

Question-8

1. For the figure below draw the sequence networks.
2. Draw the connections of the sequence networks for a single line to ground fault at bus number 4.
3. Using MiPower, simulate the SLG fault at (i) bus no 4 (ii) bus no 3.Compare the fault currents in the two cases.
4. Analyze the results of the simulation study in terms of sequence currents, line currents and linevoltages.
5. Compare the fault currents for SLG and 3-phase symmetrical fault at bus no 3.



Question-9

1. The cost functions of three plants in Rs/h is given by

   $$F1 = 350 + 7.2\, P_{G1} + 0.004\, P_{G1}^2$$
   $$F2 = 500 + 7.3\, P_{G2} + 0.0025\, P_{G2}^2$$
   $$F3 = 600 + 6.74\, P_{G3} + 0.003\, P_{G3}^2$$

   The generation is in MW in the above functions. The generator limits are the same for all theplants and given by

   $$125 \leq PG \leq 300 \text{ MW}$$

   Write a program in MATLAB to determine the optimal economic dispatch for a demand of (i)450 MW (ii) 600 MW using an initial λ of 6.
2. Repeat the problem with another initial value of λ. Comment on the result.
3. Compare the cost of optimal dispatch with that when the demand is shared equally between theplants.

Question-10

1. Write a program in MATLAB to obtain optimal economic schedule for the following data:The fuel cost of two plants is given by

   $$F1=200+10.333P_{G1}+0.00889P_{G1}^2 \text{Rs/h}$$
   $$F2=240+10.833P_{G2}+0.00741P_{G2}^2 \text{Rs/h}$$

   The demandis 150MW. The transmission loss is given by$P_{loss}=0.001P_{G1}^2+0.002P_{G2}^2$
2. What is the schedule if loss is neglected?
3. Repeat question 1, for a demand of 200MW.

Question-11

1. Write the swing equation as two first order differential equations.
2. Give equations for solving the above using modified Euler's method
3. Write a program in MATLAB to solve the swing equation using Modified Euler's method withfollowing data.

   Pmax1=1.714
   puPmax2=0.63
   pu
   Pmax3=1.333
   pu
   Power transferred =0.8
   puH= 5.2
   Fault clearing time =0.125
   secsFrequency=50 Hz

4. Draw the swing curve for two different step sizes.

Question-12

1. Write the swing equation as two first order differential equations.
2. Give equations for solving the above using RK 4^{th} order method
3. Write a program in MATLAB to solve the swing equation using RK 4^{th} order method withfollowing data.

   Pmax1=1.714
   puPmax2=0.63
   pu
   Pmax3=1.333
   pu
   Power transferred =0.8
   puH= 5.2
   Fault clearing time =0.125
   secsFrequency=50 Hz

4. Draw the swing curve for two different step sizes.

VIVA VOICE

1. What is single line diagram?

A single line diagram is a diagrammatic representation of power system in which the components are represented by their symbols and the interconnection between them are shown by a single straight line.

2. What are the components of a power system?

The components of a power system are Generators, Power transformers, Transmission lines, Substation transformers, Distribution transformers and Loads.

3. Define per unit value.

The per unit value of any quantity is defined as the ratio of actual value of the quantity to base value of the quantity.

Per unit = Actual value / Base value

4. What is the need for base value?

The components or various sections of power system may operate at different voltage and power levels. It will be convenient for analysis of power system if the voltage, power, current and impedance ratings of components of power system are expressed with a common value called base value. Hence for analysis purpose a base value is chosen for voltage, power, current and impedance.

5. Write the equation for converting the p.u. impedance expressed in one base to another.

$Z_{p.u,new}$ = Zp.u$_{,old}$) * ($kV_{b,old}$ / $kV_{b,old}$) * ($MVA_{b,new}$ / $MVA_{b,old}$)

6. What are the advantages of per unit computations?

- manufacturers usually specify the impedance of a device or machine in per unit on the basis of the name plate details.
- The p.u. values of widely different rating machines lie within a narrow range eventhough the ohmic values has a very large range.
- The p.u. impedance of circuit element connected by a transformer expressed on a proper base will be same if it is referred to either side of a transformer.
- The p.u. impedance of a 3-phase transformer is independent of the type winding connection.

7. What are the approximations made in impedance diagram?

- The neutral reactances are neglected.
- The shunt branches in equivalent circuit of induction motor are neglected.

8. What are the approximations made in reactance diagram?

- The neutral reactance are neglected.
- The shunt branches in equivalent circuit of induction motor are neglected.
- The resistances are neglected.
- All static loads and induction motor are neglected.
- The capacitances of the transmission lines are neglected.

9. Give the equations for transforming base kV on LV side to HV side and viceversa.

Base kV on HT side = Base kV on LT side * (HT voltage rating / LT voltage rating)
Base kV on LT side = Base kV on HT side * (LT voltage rating / HT voltage rating)

10. What is a bus?

The meeting point of various components in a power system is called a bus. The bus is a conductor made of copper or aluminum having negligible resistance .At some of the buses power is being injected into the network, whereas at other buses it is being tapped by the system loads.

11. What is bus admittance matrix?

The matrix consisting of the self and mutual admittance of the network of a power system is called bus admittance matrix.

12. Name the diagonal and off-diagonal elements of bus admittance matrix.

The diagonal elements of bus admittance matrix are called self admittances of the matrix and off-diagonal elements are called mutual admittances of the buses.

13. Methods available for forming bus admittance matrix

- Direct inspection method.
- Singular transformation method.(Primitive network)

14. Write the equation to find the elements of new bus admittance matrix after eliminating n^{th} row and column in a n*n matrix.

$$Yjk = Yjk-(Y_{jn}Y_{nk} / Y_{nn})$$

15. What is bus impedance matrix?

The matrix consisting of driving point impedances and transfer impedances of the network of a power system is called bus impedance matrix.

16. Name the diagonal and off-diagonal elements of bus impedance matrix.

The diagonal elements of bus impedance matrix are called driving point impedances of the buses and off-diagonal elements are called transfer impedances of the buses.

17. What are the methods available for forming bus impedances matrix?

(1)Form the bus admittances matrix and then take its inverse to get bus impedance matrix.

(2)Directly form the bus impedance matrix from the reactance diagram. This method utilizes the techniques of modification of existing bus impedance matrix due to addition of new bus.

18. Write the four ways of adding an impedance to an existing system so as to modify bus impedance matrix.

Case 1:Adding a branch impedance Z_b from a new bus P to the reference bus.
Case 2:Adding a branch impedance Z_b from a new bus P to the existing bus q.
Case 3:Adding a branch impedance Z_b from a existing bus q to the reference bus.
Case 4:Adding a branch impedance Z_b between two existing bus h and q.

19. What is off-nominal transformer ratio?

When the voltage or turns ratio of a transformer is not used to decide the ratio of base kV then its voltage or turns ratio is called off-nominal turns ratio.

20. Information's that are obtained from a load flow study?

The information obtained from a load flow study is magnitude and phase angle of voltages, real and reactive power flowing in each line and the line losses. The load flow solution also gives the initial conditions of the system when the transient behavior of the system is to be studied.

21. Need for load flow study?

The load flow study of a power system is essential to decide the best operation of existing system and for planning the future expansion of the system. It is also essential for designing a new power system.

22. Quantities associated with each bus in a system?

Each bus in a power system is associated with four quantities and they are real power (P), reactive power (Q), magnitude of voltage (V), and phase angle of voltage (δ).

23. Work involved (or) to be performed by a load flow study?

(i). Representation of the system by a single line diagram
(ii). Determining the impedance diagram using the information in single line diagram
(iii). Formulation of network equation
(iv). Solution of network equations

24. Iterative methods to solve load flow problems?

The load flow equations are non linear algebraic equations and so explicit solution as not possible. The solution of non linear equations can be obtained only by iterative numerical techniques.

25. Methods mainly used for solution of load flow study?

The Gauss seidal method, Newton Raphson method and Fast decouple methods.

25. What is Flat voltage start?

In iterative method of load flow solution, the initial voltages of all buses except slack bus assumed as 1+j0 p.u. This is referred to as flat voltage start.

26. Different types of buses in a power system

Types of bus	Known or specified quantities	Unknown quantities or quantities to be determined
Slack or Swing or Reference bus	V, δ	P,Q
Generator or Voltage control or PV bus	P, V	Q, δ
Load or PQ bus	P, Q	V, δ

27. What is the need for slack bus?

The slack bus is needed to account for transmission line losses. In a power system the total power generated will be equal to sum of power consumed by loads and losses. In a power system only the generated power and load power are specified for buses. The slack bus is assumed to generate the power required for losses. Since the losses are unknown the real and reactive power are not specified for slack bus. They are estimated through the solution of line flow equations.

28. What is the effect of acceleration factor in load flow study?

In load flow solution by iterative methods, the number of iterations can be reduced if the correction voltage at each bus is multiplied by some constant. The multiplication of the constant will increase the amount of correction to bring the voltage closer to the value it is approaching. The multipliers that accomplish this improved converged are called acceleration factors. An acceleration factor of 1.6 is normally used in load flow problems.

29. When Generator buses are treated as load bus?

If the reactive power constraint of a generator bus violates the specified limits then the generator is treated as load bus.

30. Write the most important mode of operation of power system and mention the major problems encountered with it.

Symmetrical steady state is the most important mode of operation of power system. Three major problems are encountered in this mode of operation. They are, 1) Load flow problem

2) Optimal load scheduling problem
3) Systems control problem

31. Why power flow analysis is made?

Power flow analysis is performed to calculate the magnitude and phase angle of voltages at the buses and also the active power and reactive voltamperes flow for the given terminal or bus conditions. The variables associated with each bus or node are,

a. Magnitude of voltage |V|
b. Phase angle of voltage δ
c. Active power, P
d. Reactive voltamperes, Q

32. What is power flow study or load flow study?

The study of various methods of solution to power system network is referred to as load study. The solution provides the voltages at various buses, power flowing in Various lines and line losses.

33. What are the different types of buses in a power system?

The buses of a power system can be classified into three types based on the quantities being specified for the buses, which are as follows:

a. Load bus or PQ bus (P and Q are specified)
b. Generator bus or voltage controlled bus or PV bus (P and V are specified)
c. Slack bus or swing bus or reference bus (|V| and δ are specified)

34. Define voltage controlled bus(generator bus/PV bus).

A bus is called voltage controlled bus if the magnitude of voltage |V| and real power (P) are specified for it. In a voltage controlled bus, the magnitude of the voltage is not allowed to change. Voltage controlled bus is also called as Generator bus and PV bus.

35. What is PQ bus(load bus)?

A bus is called PQ bus or load bus when real and reactive components of power are specified for the bus. In a load bus, the voltage is allowed to vary within permissible limits.

36. What is swing bus(slack bus/reference bus)?

A bus is called swing bus when the magnitude and phase of bus voltage are specified for it. The swing bus is the reference bus for load flow solution and it is required for accounting for the line losses. Usually one of the generator bus is selected as the swing bus.

37. How will you account for voltage controlled buses in the load flow algorithm?

The acceleration factor is a real quantity and it modifies the magnitude of bus voltage alone. Since in voltage controlled bus, the magnitude of bus voltage is not allowed to change, the acceleration factor is not used for voltage controlled bus.

38. Why do we go for iterative methods to solve load flow problems?

The load (or power) flow equations are nonlinear algebraic equations and so explicit solution is not possible. The solution of nonlinear equations can be obtained only by iterative numerical techniques.

39. When the generator bus is treated as load bus? What will be the reactive power and bus voltage when the generator bus is treated as load bus?

If the reactive power of a generator bus violates the specified limits, then the generator bus is treated as load bus. The reactive power of that particular bus is equated to the limit it has violated and the previous iteration value of bus voltage is used for calculating current iteration value.

40. What are the advantages of Gauss-Seidel method?

The advantages of Gauss-Seidel method are,

a. Calculations are simple and so the programming task is less
b. The memory requirement is less
c. Useful for small systems.

41. What are the disadvantages of Gauss-Seidel method?

The disadvantages of Gauss-Seidel method are,

a. Requires large number of iterations to reach convergence.
b. Not suitable for large systems.
c. Convergence time increases with size of the system.

42. How approximation is performed in Newton-Raphson method?

In Newton-Raphson method, the set of non-linear simultaneous (load flow) equations are approximated to a set of linear simultaneous equations using Taylor's series expansion and the terms are limited to first order approximation.

43. What is Jacobian matrix? How the elements of Jacobian matrix are computed?

The matrix formed from the derivates of load flow equations is called Jacobian matrix and it is denoted by J.

The elements of Jacobian matrix will change in every iteration. In each iteration, the elements of the Jacobian matrix are obtained by partially differentiating the load flow equations with respect o unknown variable and then evaluating the first derivates using the solution of previous iteration.

44. What are the advantages of Newton-Raphson method?

The advantages of Newton-Raphson method are,

a. This load flow method is faster, more reliable and he results are accurate.
b. Requires less number of iterations for convergence.
c. The number of iterations are independent of the size of the system.
d. Suitable for large system.

45. What are the disadvantages of Newton-Raphson method?

The disadvantages of Newton-Raphson method are,

a. Programming is more complex.
b. The memory requirement is more.
c. Computational time per iteration is higher due to larger number of calculations per iteration.

46. Mention (any) three advantages of N-R method over G-S method?

The three advantages of N-R method over G-S method are,

a. The N-R method has quadratic convergence characteristics and so converges faster than G-S method.
b. The number of iterations for convergence is independent of the system in N-R method.
c. In N-R method, the convergence is not affected by the choice of slack bus.

47. Compare G-S method and N-R methods of load flow solutions.

G-S method	N-R method
1. The variables are expressed in rectangular co-ordinates. 2. Computation time per iteration is less. 3. It has linear convergence characteristics. 4. The number of iterations required for convergence increase with size of the system. 5.The choice of slack bus is critical.	1. Variables are expressed in polar co-ordinates. 2. Computation time per iteration is more 3. It has quadratic convergence characteristics. 4.The number of iterations are independent of the size of the system. 5. The choice of slack bus is arbitrary.

48. How the convergence of N-R method is speeded up?

The convergence can be speeded up in N-R method by using Fast Decoupled Load Flow (FDLF) algorithm. In FDLF method, the weak coupling between P-δ and Q-V are decoupled and then the equations are further simplified using the knowledge of practical operating conditions of a power system.

49. How the disadvantages of N-R method are overcome?

The disadvantage of large memory requirement can be overcome by decoupling the weak coupling between P-δ and Q-V (i.e., using decoupled load flow algorithm). The disadvantage of large computational time per iteration can be reduced by simplifying the decoupled load flow equations. The simplifications are based on the practical operating conditions of a power system.

50. Define primitive network.

Primitive network is a set of unconnected elements which provides information regarding the characteristics of individual elements only. The performance equations of primitive network are given below.

$V + E = ZI$ (In Impedance form)

$I + J = YV$ (In Admittance form) where V and I are the element voltage and current vectors respectively.

J and E are source vectors.

Z and Y are the primitive Impedance and Admittance matrices respectively.

51. Explain bus incidence matrix.

For the specific system, we can obtain the following relation (relation between element voltage and bus voltage).

$V = A\,V_{BUS}$

where A is the bus incidence matrix, which is a rectangular and singular matrix. Its elements are found as per the following rules.

$a_{ik} = 1$, if i^{th} element is incident to and oriented away from the k^{th} node (bus).

$= -1$, if i^{th} element is incident to but oriented towards the k^{th} node.

$= 0$, if i^{th} element is not incident to the k^{th} node.

52. What is bus admittance matrix?

The matrix consisting of the self and mutual admittance of the power system network is called bus admittance matrix. It is given by the admittance matrix Y in the node basis matrix equation of a powersystem and it is denoted as Y_{bus}. Bus admittance matrix is a symmetrical matrix.

53. Write the equation for the bus admittance matrix.

The equation for bus admittance matrix is, $Y_{bus}V = I$where

Y_{bus} = Bus admittance matrix of order (n x n)
V = Bus voltage matrix of order (n x1)
I = Current source matrix of order (n x1)
n = Number of independent buses in the system

54. Mention the advantages of bus admittance matrix, Y_{bus}.

i) Data preparation is simple.
ii) Formation and modification is easy.
iii) Since the bus admittance matrix is sparse matrix(i.e., most of its elements are zero), the computer memory requirements are less.

55. Explain the requirements of planning the operation of a power system.

Planning the operation of a power system requires load studies, fault calculations, the design of means for protecting the system against lightning and switching surges and against short circuits, and studies of the stability of the system.

56. Define steady state operating condition.

A power system is said to be in a steady state operating condition, if all the measured(or calculated) physical quantities describing the operating condition of the system can be considered constant for the purpose of analysis.

57. What is a disturbance and what are the two types of disturbances?

If a sudden change or sequence of changes occurs in one or more of the system parameters or one or more of its operating quantities, the system is said to have undergone a disturbance from its steady state operating condition.

The two types of disturbances in a power system are,

i) Large disturbance ii) Small disturbance

58. What is a small disturbance? Give example.

If the power system is operating in a steady state condition and it undergoes change, which can be properly analyzed by linearized versions of its dynamic and algebraic equations, a small disturbance is said to have occurred.

Example of small disturbance is a change in the gain of the automatic voltage regulator in the excitation system of a large generating unit.

59. What is a large disturbance? Give some examples.

A large disturbance is one for which the nonlinear equations describing the dynamics of the power system cannot be validly linearized for the purpose of analysis.

Examples of large disturbances are transmission system faults, sudden load changes, loss of generating units and line switching.

60. When is a power system said to be steady-state stable?

The power system is steady state stable for a particular steady-state operating condition if, following a small disturbance, it returns to essentially the same steady state condition of operation.

61. When is a power system said to be transiently stable?

If the machines of the system are found to remain essentially in synchronism within the first second following a system fault or other large disturbance, the system is considered to be transiently stable.

62. What is transient state of the power system?

The state of the system in the first second following a system fault or large disturbance is called the transient state of the power system.

63. Define per unit value of any electrical quantity.

The per unit value of any electrical quantity is defined as the ratio of the actual value of the quantity to its base value expressed as a decimal.

$$Perunitvalue = \frac{Actual\ value}{Base\ value}$$

64. What are the quantities whose base values are required to represent the power system by reactance diagram?

The base value of voltage, current, power and impedance are required to represent the power system by reactance diagram. Selection of base values for any two of them determines the base values of the remaining two. Usually the base values of voltage and power are chosen in kilovolt and kVA or mVA respectively. The base values of current and impedance are calculated using the chosen bases.

65. What is the need for base values?

The components of various sections of power system may operate at different voltage and power levels. It will be convenient for analysis of power system if the voltage, power, current and impedance ratings of power system components are expressed with reference to a common value called base value. Then all the voltages, power, current and impedance ratings of the components are expressed as a percent or per unit of the base value.

66. List the advantages of per unit computations.

(1) The per unit impedance referred to either side of a single phase transformer is the same.
(2) The per unit impedance referred to either side of a three phase transformer is the same regardless of the three phase connections whether they are Y-Y, Δ-Δ or Δ-Y
(3) The chance of confusion between the line and phase quantities in a three phase balanced system is greatly reduced.
(4) The manufacturers usually provide the impedance values in per unit.
(5) The computational effort in power system is very much reduced with the use of per unit quantities.

67. What are the factors that affect the transient stability?

The transient stability is generally affected by two factors namely,

1.Type of fault   2. Location of fault.

68. List the methods of improving the transient stability limit of a power system.

1.Increase of system voltage, use of AVR.
2.Use of high speed excitation systems.
3.Reduction in system transfer reactance.
4.Use of high speed reclosing breakers.

69. What is meant by stability study?

The procedure of determining the stability of a system upon occurrence of a disturbance followed by various switch off and switch on actions is called a stability study.

70. What is meant by short circuit fault?

Short circuit faults involve power conductor or conductors-to-ground or short circuit between conductors. These faults are characterized by increase in current and fall in voltage and frequency.

71. What is a reactor?

Reactor is a coil, which has high inductive reactance as compared to its resistance and is used to limit the short circuit current during fault conditions.

72. What is meant by a fault?

A fault in a circuit is any failure which interrupts with the normal flow of current. The faults are associated with abnormal change in current, voltage and frequency of the power system. The faults may cause damage to the equipments, if it is allowed to persist for a long time.

73. Give the reason for faults in power system?

Faults occur in a power system due to insulation failure of equipments, flashover of lines initiated by a lightening stroke, permanent damage to conductors and towers or accidental faulty operations.

74. List the various types of symmetrical and unsymmetrical faults.

Symmetrical fault: Three phase fault

Unsymmetrical faults:

1.Single line-to-ground fault
2.Line-to-line fault
3.Double line-to-ground fault

75. For a fault at a given location, rank the various faults in the order of severity.

In a power system, the most severe fault is three phase fault and less severe fault is open conductor fault. The various faults in the order of decreasing severity are,

1) 3 phase fault
2) Double line-to-ground fault
3)Line-to-line fault
4)Single line-to-ground fault
5)Open conductor fault

76. What is meant by fault calculations?

The fault condition of a power system can be divided into subtransient, transient, and steady state periods. The currents in the various parts of the system and in the fault locations are different in these periods. The estimation of these currents for various types of faults at various locations in the system is commonly referred to as fault calculations.

77. **What is synchronous reactance?**

The synchronous reactance is the ratio of induced emf and the steady state rms current (i.e., it is the reactance of a synchronous machine under steady state condition). It is the sum of leakage reactance and the reactance representing armature reaction. It is given by,

$$X_s = X_l + X_a$$

Where,

X_s = Synchronous reactance

X_l = Leakage reactance

X_a = Armature reaction reactance.

78. Define subtransient reactance.

The subtransient reactance is the ratio of induced emf on no-load and the subtransient symmetrical rms current, (i.e., it is the reactance of a synchronous machine under subtransient condition).

79. Define transient reactance.

The transient reactance is the ratio of induced emf on no-load and the transient symmetrical rms current. (i.e.,it is the reactance of synchronous machine under transient condition).

80. What is the significance of subtransient reactance and transient reactance in short circuit studies?

The subtransient reactance can be used to estimate the initial value of fault current immediately on the occurrence of the fault. The maximum momentary short circuit current rating of the circuit breaker used for protection or fault clearing should be less than this initial fault current.

The transient reactance is used to estimate the transient state fault current. Most of the circuit breakers open their contacts only during this period. Therefore for a circuit breaker used for fault clearing (or protection), its interrupting short circuit current rating should be less than the transient fault current.

X_d' = Direct axis transient reactance

E_g = RMS voltage from one terminal to neutral at no load.

81. Write the equation for subtransient and transient internal voltage of the generator.

The equation for subtransient internal voltage is,

$$E_g'' = V_t + jI_L X_d''$$

Transient internal voltage is,

$$E_g' = V_t + jI_L X_d'$$

where

E_g'' = Subtransient internal voltage of generator

E_g' = Transient internal voltage of generator

V_t = Terminal voltage

I_L = Load current

X_d'' =Direct axis subtransient reactance
X_d' =Direct axis transient reactance

82. Write the equation for subtransient and transient internal voltage of the motor. The equation for subtransient internal voltage is,

$$E_m'' = V_t - jI_L X_d''$$

Transient internal voltage is,

$$E_m' = V_t - jI_L X_d'$$ s where

E_m'' = Subtransient internal voltage of generator
E_m' = Transient internal voltage of generator
V_t = Terminal voltage
I_L = Load current
X_d'' =Direct axis subtransient reactance
X_d' =Direct axis transient reactance

83. Define doubling effect and DC off-set current.

Doubling effect:

If a symmetrical fault occurs when the voltage wave is going through zero then the maximum momentary short circuit current will be double the value of maximum symmetrical short circuit current. This effect is called doubling effect.

DC off-set current:

The unidirectional transient component of short circuit current is called DC offset current.

84. Differentiate between subtransient and transient reactance.

Subtransient reactance	Transient reactance
1) This is the ratio of induced emf and subtransient current. 2) Flux created by induced currents in the damper winding is included. 3) This is the smallest reactance among the reactance values. 4) This cannot be extrapolated.	1) This is the ratio of induced emf and transient current. 2) There is no damper winding and hence no flux is created. 3) This is larger than the subtransient reactance. 4) This can be extrapolated backwards in time

85. What are symmetrical components?

An unbalanced system of N related vectors can be resolved into N systems of balancedvectors called symmetrical components. Positive sequence components Negative sequence component Zero sequence components.

86. Write the symmetrical components of three phase system.

In a 3-phase system, the three unbalanced vectors (either current or voltage vectors) can be resolved into three balanced system of vectors. They are,

1) Positive sequence components

2) Negative sequence components
3) Zero sequence components.

87. Define negative sequence and zero sequence components.

Negative sequence components consist of three phasors equal in magnitude, displaced from each other by 120° in phase, and having the phase sequence opposite to that of the original phasors. V_{a2}, V_{b2} and V_{c2} are the negative sequence components of V_a,

V_b and v_c.

Zero sequence components consist of three phasors equal in magnitude and with zero phase displacement from each other. V_{ao}, V_{bo} and V_{co} are the zero sequence components of V_a, V_b and V_c.

88. How do you classify steady state stability limit. Define them.

Depending on the nature of the disturbance, the steady state stability limit is classified into,

a. **Static stability limit** refers to steady state stability limit that prevails without the aid of regulating devices.
b. **Dynamic stability limit** refers to steady state stability limit prevailing in an unstable system with the help of regulating devices such as speed governors, voltage regulators, etc.

89. What are the machine problems seen in the stability study.

1. Those having one machine of finite inertia machines swinging with respect to an infinite bus
2. Those having two finite inertia machines swinging with respect to each other.

90. Give the expression for swing equation. Explain each term along with their units.

Where H = Inertia constant in MJ/MVA.
f = Frequency in Hz.
M = Inertia constant in p.u.
P_m= Mechanical power input to the system (neglecting mechanical losses) in p.u.
P_e = Electrical power output of the system (neglecting electrical losses) in p.u.

91. What are the assumptions made in solving swing equation?

1) Mechanical power input to the machine remains constant during the period of electromechanical transient of interest.
2) Rotor speed changes are insignificant that had already been ignored in formulating the swing equations.
3) Effect of voltage regulating loop during the transient are ignored.

92. Define swing curve. What is the use of swing curve?

The swing curve is the plot or graph between the power angle δ, and time, t. It is usually plotted for a transient state to study the nature of variation in δ for a sudden large disturbance. From the nature of variations of δ, the stability of a system for any disturbance can be determined.

93. Give the control schemes included in stability control techniques?

The control schemes included in the stability control techniques are:

a. Excitation systems

b. Turbine valve control

c. Single pole operation of circuit breakers

d. Faster fault clearing times

94. What are the systems design strategies aimed at lowering system reactance?

The system design strategies aimed at lowering system reactance are:

a. Minimum transformer reactance

b. Series capacitor compensation of lines

c. Additional transmission lines.

95. What are coherent machines? (APR/MAY 2004)

Machines which swing together are called coherent machines. When both ωs and δ are expressed in electrical degrees or radians, the swing equations for coherent machines can be combined together even though the rated speeds are different. This is used in stability studies involving many machines.

96. State equal area criterion. (NOV/DEC 2004)

In a two machine system under the usual assumptions of constant input , no damping and constant voltage being transient reactance , the angle between the machines either increases or else, after all disturbances have occurred oscillates with constant amplitude. There is a simple graphical method of determining whether the system comes to rest with respect to each other. This is known as equal area criterion

97. What are various faults that increase severity of equal area criterion?

The various faults that increases severity of equal area criterion are,

a) Single line to ground fault

b) Line to line fault

c) Double line to ground fault

d) Three phase fault

98. List the types of disturbances that may occur in a single machine infinite bus bar system of the equal area criterion stability

The types of disturbances that may occur are,

Sudden change in mechanical input

Effect of clearing time on stability

Sudden loss of one of parallel lines

Sudden short circuit on one of parallel lines

i) Short circuit at one end of line

ii) Short circuit away from line ends

iii) Reclosure

99. Define critical clearing angle

The critical clearing angle δcc is the maximum allowable change in the power angle δ before clearing the fault , without loss of synchronism.

100. Define critical clearing time.

The critical clearing time , tcc can be defined as the maximum time delay that can be allowed to clear a fault without loss of synchronism . The time corresponding to the critical clearing angle is called critical clearing time tcc.

101. What are the assumptions that are made inorder to simplify the computational task in stability studies?

The assumptions are,

- The D.C offset currents and harmonic components are neglected. The currents and voltages are assumed to have fundamental component alone.
- The symmetrical components are used for the representation of unbalanced faults.
- It is assumed that the machine speed variations will not affect the generated voltage.

102. What is Multimachine stability?

If a system has any number of machines, then each machine is listed for stability by advancing the angular position, δ of its internal voltage and noting whether the electric power output of the machine increases (or) decreases. If it increases, i.e if $\partial Pn / \partial \delta n > 0$ then machine n is stable. If every machine is stable, then the system having any number of machine is stable.

103. What is meant by an infinite bus?

The connection or disconnection of a single small machine on a large system would not affect the magnitude and phase of the voltage and frequency. Such a system of constant voltage and constant frequency regardless of the load is called infinite bus bar system or infinite bus.

104. List the assumptions made in multimachine stability studies.

The assumptions made are,

- The mechanical power input to each machine remains constant during the entire period of the swing curve computation
- Damping power is negligible
- Each machine may be represented by a constant transient reactance in series with a constant transient voltage.
- The mechanical rotor angle of each machine coincides with δ , the electrical phase angle of the transient internal voltage.

105. Explain the concept synchronous speed.

The mechanical torque Tm and the electrical torque Te are considered positive for synchronous generator. Tm is the resultant shaft torque which tends to accelerate the rotor in the positive θm direction of rotation . Under steady-state operation of the generator Tm and Te are equal and the accelerating torque Ta is zero. Hence there is no acceleration of deceleration of the rotor, masses and the resultant constant speed is the synchronous speed.