



**DEPARTMENT OF  
ELECTRICAL AND ELECTRONICS ENGINEERING**

**EE 6711- POWER SYSTEM SIMULATION LABORATORY**

VII SEMESTER - R 2013

**LABORATORY MANUAL**

Name : \_\_\_\_\_  
Register No. : \_\_\_\_\_  
Class : \_\_\_\_\_

**VISION**

is committed to provide highly disciplined, conscientious and enterprising professionals conforming to global standards through value based quality education and training.

**MISSION**

- To provide competent technical manpower capable of meeting requirements of the industry
- To contribute to the promotion of Academic Excellence in pursuit of Technical Education at different levels
- To train the students to sell his brawn and brain to the highest bidder but to never put a price tag on heart and soul

## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

**VISION**

To impart professional education integrated with human values to the younger generation, so as to shape them as proficient and dedicated engineers, capable of providing comprehensive solutions to the challenges in deploying technology for the service of humanity

**MISSION**

- To educate the students with the state-of-art technologies to meet the growing challenges of the electronics industry
- To carry out research through continuous interaction with research institutes and industry, on advances in communication systems
- To provide the students with strong ground rules to facilitate them for systematic learning, innovation and ethical practices



## **PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)**

### **1. Fundamentals**

To provide students with a solid foundation in Mathematics, Science and fundamentals of engineering, enabling them to apply, to find solutions for engineering problems and use this knowledge to acquire higher education

### **2. Core Competence**

To train the students in Electrical and Electronics technologies so that they apply their knowledge and training to compare, and to analyze various engineering industrial problems to find solutions

### **3. Breadth**

To provide relevant training and experience to bridge the gap between theory and practice which enables them to find solutions for the real time problems in industry, and to design products

### **4. Professionalism**

To inculcate professional and effective communication skills, leadership qualities and team spirit in the students to make them multi-faceted personalities and develop their ability to relate engineering issues to broader social context

### **5. Lifelong Learning/Ethics**

To demonstrate and practice ethical and professional responsibilities in the industry and society in the large, through commitment and lifelong learning needed for successful professional career

## **PROGRAMME OUTCOMES (POs)**

- a. To demonstrate and apply knowledge of Mathematics, Science and engineering fundamentals in Electrical and Electronics Engineering field
- b. To design a component, a system or a process to meet the specific needs within the realistic constraints such as economics, environment, ethics, health, safety and manufacturability
- c. To demonstrate the competency to use software tools for computation, simulation and testing of electrical and electronics engineering circuits
- d. To identify, formulate and solve electrical and electronics engineering problems
- e. To demonstrate an ability to visualize and work on laboratory and multidisciplinary tasks
- f. To function as a member or a leader in multidisciplinary activities
- g. To communicate in verbal and written form with fellow engineers and society at large
- h. To understand the impact of Electrical and Electronics Engineering in the society and demonstrate awareness of contemporary issues and commitment to give solutions exhibiting social responsibility
- i. To demonstrate professional & ethical responsibilities
- j. To exhibit confidence in self-education and ability for lifelong learning
- k. To participate and succeed in competitive exams

## EE6711 – POWER SYSTEM SIMULATION LABORATORY

### SYLLABUS

#### COURSE OBJECTIVES

To provide better understanding of power system analysis through digital simulation.

#### LIST OF EXPERIMENTS:

1. Computation of Parameters and Modeling of Transmission Lines
2. Formation of Bus Admittance and Impedance Matrices and Solution of Networks
3. Load Flow Analysis - I Solution of load flow and related problems using Gauss- Seidel Method.
4. Load Flow Analysis - II: Solution of load flow and related problems using Newton Raphson.
5. Fault Analysis
6. Transient and Small Signal Stability Analysis: Single-Machine Infinite Bus System
7. Transient Stability Analysis of Multi machine Power Systems
8. Electromagnetic Transients in Power Systems
9. Load –Frequency Dynamics of Single- Area and Two-Area Power Systems
10. Economic Dispatch in Power Systems.

#### COURSE OUTCOMES

1. Ability to understand the concept of MATLAB programming in solving power systems problems.
2. Ability to understand the concept of MATLAB programming in solving parameters of transmission lines.
3. Ability to understand the concept of MATLAB programming in solving medium transmission line parameters.
4. Ability to understand the concept of MATLAB programming in formation of bus admittance and impedance matrices.
5. Ability to understand the concept of MATLAB / simulink modeling of single area system.
6. Ability to understand the concept of MATLAB / simulink modeling of two area system.
7. Ability to understand the concept of MATLAB programming in analyzing transient and small signal stability analysis of SMIB system.
8. Ability to understand the concept of MATLAB programming in solving economic dispatch in power systems.
9. Ability to understand the concept of MATLAB Programming in analyzing transient stability analysis of multi machine infinite bus system.
10. Ability to understand the concept of MATLAB programming in solving power flow analysis using Gauss siedel method.
11. Ability to understand the concept of MATLAB programming in solving power flow analysis using Newton Raphson method.
12. Ability to understand the concept of MATLAB programming in solving fault analysis in power system.
13. Ability to understand the concept of MATLAB programming in analyzing transient stability analysis of multi machine power systems.
14. Ability to understand the concept of MATLAB / Simulink modeling of FACTS devices.

**EE6711 – POWER SYSTEM SIMULATION LABORATORY****CONTENTS**

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**Expt. No.1:****INTRODUCTION TO MATLAB****Aim:**

To procure sufficient knowledge in MATLAB to solve the power system Problems

**Software required:**

MATLAB

**Theory:****1. Introduction to MATLAB:**

MATLAB is a high performance language for technical computing. It integrates computation, visualization and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. MATLAB is numeric computation software for engineering and scientific calculations. MATLAB is primary tool for matrix computations. MATLAB is being used to simulate random process, power system, control system and communication theory. MATLAB comprising lot of optional tool boxes and block set like control system, optimization, and power system and so on.

**1.1 Typical uses:**

- Mathematics tools and computation
- Algorithm development
- Modeling, simulation and prototype
- Data analysis, exploration and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

MATLAB is a widely used tool in electrical engineering community. It can be used for simple mathematical manipulation with matrices for understanding and teaching basic mathematical and engineering concepts and even for studying and simulating actual power system and electrical system in general. The original concept of a small and handy tool has evolved replace and/or enhance the usage of traditional simulation tool for advanced engineering applications to become an engineering work house. It is now accepted that MATLAB and its numerous tool boxes

**1.2 Getting started with MATLAB:**

To open the MATLAB applications double click the MATLAB icon on the desktop. To quit from MATLAB type...

>> quit

(Or)

>>exit

To select the (default) current directory click ON the icon [...] and browse for the folder named "D:\SIMULAB\xxx", where xxx represents roll number of the individual candidate in which a folder should be created already.

When you start MATLAB you are presented with a window from which you can enter commands interactively. Alternatively, you can put your commands in an M- file and execute it at the MATLAB prompt. In practice you will probably do a little of both. One good approach is to incrementally create your file of commands by first executing them.

M-files can be classified into following 2 categories,

- i) Script M-files – Main file contains commands and from which functions can also be called
- ii) Function M-files – Function file that contains function command at the first line of the M-file

M-files to be created should be placed in your default directory. The M-files developed can be loaded into the work space by just typing the M-file name. To load and run a M-file named "ybus.m" in the workspace

```
>> ybus
```

These M-files of commands must be given the file extension of ".m". However M-files are not limited to being a series of commands that you don't want to type at the MATLAB window, they can also be used to create user defined function. It turns out that a MATLAB tool box is usually nothing more than a grouping of M-files that someone created to perform a special type of analysis like control system design and power system analysis. One of the more generally useful MATLAB tool boxes is simulink – a drag and-drop dynamic system simulation environment. This will be used extensively in laboratory, forming the heart of the computer aided control system design (CACSD) methodology that is used.

```
>> Simulink
```

At the MATLAB prompt type simulink and brings up the "Simulink Library Browser". Each of the items in the Simulink Library Browser are the top level of a hierarchy of palette of elements that you can add to a simulink model of your own creation. The "simulink" palette contains the majority of the elements used in the MATLAB. Simulink has built into it a variety of integration algorithm for integrating the dynamic equations. You can place the dynamic equations of your system into simulink in four ways.

- 1 Using integrators
2. Using transfer functions
3. Using state space equations

#### 4. Using S- functions (the most versatile approach)

Once you have the dynamics in place you can apply inputs from the "sources" palettes and look at the results in the "sinks" palette. Finally, the most important MATLAB feature is help. At the MATLAB Prompt simply typing helpdesk gives you access to searchable help as well as all the MATLAB manuals.

```
>> helpdesk
```

To get the details about the command name sqrt, just type...

```
>> help sqrt
```

(like  $5+j8$ ) and matrices with the same ease as manipulating scalars (like 5,8). Before diving into the actual commands everybody must spend a few moments reviewing the main MATLAB data types. The three most common data types you may see are,

1) arrays 2) strings 3) structures Where sqrt is the command name and you will get pretty good description in the MATLAB window as follows.

/SQRT Square root. SQRT(X) is the square root of the elements of X. Complex results are produced if X is not positive.

### 1.3 MATLAB workspace:

The workspace is the window where you execute MATLAB commands (Ref. figure-1). The best way to probe the workspace is to type whos. This command shows you all the variables that are currently in workspace. You should always change working directory to an appropriate location under your user name. Another useful workspace like command is

```
>>clear all
```

It eliminates all the variables in your workspace. For example, start MATLAB and execute the following sequence of commands

```
>>a=2;
```

```
>>b=5;
```

```
>>whos
```

```
>>clear all
```

The first two commands loaded the two variables a and b to the workspace and assigned value of 2 and 5 respectively. The clear all command clear the variables available in the work space. The arrow keys are real handy in MATLAB. When typing in long expression at the command line, the up arrow scrolls through previous commands and down arrow advances the other direction. Instead of retyping a previously entered command just hit the up arrow until you find it. If you need to change it slightly the other arrows let you position the cursor anywhere. Finally any DOS command can be entered in MATLAB as long as it is preceded by any exclamation mark.



### 1.3 MATLAB data types:

The most distinguishing aspect of MATLAB is that it allows the user to manipulate vectors. As for as MATLAB is concerned a scalar is also a  $1 \times 1$  array. For example clear your workspace and execute the commands.

```
>>a=4.2;  
>>A=[1 4;6 3];  
>>whos
```

Two things should be evident. First MATLAB distinguishes the case of a variable name and that both `a` and `A` are considered arrays. Now let's look at the content of `A` and `a`.

```
>>a  
>>A
```

Again two things are important from this example. First anybody can examine the contents of any variables simply by typing its name at the MATLAB prompt. When typing in a matrix space between elements separate columns, whereas semicolon separate rows. For practice, create the matrix in your workspace by typing it in all the MATLAB prompt.

```
>>B= [3 0 -1; 4 4 2;7 2 11];
```

(use semicolon(`:`) to represent the end of a row)

```
>>B
```

Arrays can be constructed automatically. For instance to create a time vector where the time points start at 0 seconds and go up to 5 seconds by increments of 0.001

```
>>mytime =0:0.001:5;
```

Automatic construction of arrays of all ones can also be created as follows,

```
>>myone=ones (3,2)
```

### 1.4 Scalar versus array mathematical operation:

Since MATLAB treats everything as an array, you can add matrices as easily as scalars.

Example:

```
>>clear all  
>> a=4;  
>> A=7;  
>>alpha=a+A;  
>>b= [1 2; 3 4];  
>>B= [6 5; 3 1];
```

```
>>beta=b+B
```

The violation of the rules in matrix algebra can be understood by the following example.

```
>>clear all
```

```
>>b=[1 2;3 4];
```

```
>>B=[6 7];
```

```
>>beta=b*B
```

In contrast to matrix algebra rules, the need may arise to divide, multiply, raise to a power one vector by another, element by element. The typical scalar commands are used for this "+, -, /, \*, ^" except you put a "." in front of the scalar command. That is, if you need to multiply the elements of [1 2 3 4] by [6 7 8 9], just

```
>> [1 2 3 4].*[6 7 8 9]
```

## 1.6 Conditional statements :

Like most programming languages, MATLAB supports a variety of conditional statements and looping statements.

To explore these simply type

```
>>help if
```

```
>>help for
```

```
>>help while
```

Example :

```
>>if z=0
```

```
>>y=0
```

```
>>else
```

```
>>y=1/z
```

```
>>end
```

]Looping :

```
>>for n=1:2:10
```

```
>>s=s+n^2
```

```
>>end
```

- Yields the sum of  $1^2+3^2+5^2+7^2+9^2$

## 1.7 Plotting:

MATLAB's potential in visualizing data is pretty amazing. One of the nice features is that with the simplest of commands you can have quite a bit of capability.

Graphs can be plotted and can be saved in different formulas.

```
>> clear all  
>> t=0:10:360;  
>> y=sin (pi/180 * t);
```

To see a plot of y versus t simply type,

```
>> plot(t,y)
```

To add a label, legend, grid and title use

```
>> xlabel ('Time in sec');  
>> ylabel ('Voltage in volts')  
>> title ('Sinusoidal O/P');  
>> legend ('Signal');
```

The commands above provide the most plotting capability and represent several shortcuts to the low-level approach to generating MATLAB plots, specifically the use of handle graphics. The helpdesk provides access to a pdf manual on handle graphics for those really interested in it.

## 1.8 Functions:

As mentioned earlier, a M-file can be used to store a sequence of commands or a user-defined function. The commands and functions that comprise the new function must be put in a file whose name defines the name of the new function, with a filename extension of '.m'. A function is a generalized input/output device. We can give some input arguments and provides some output. MATLAB functions allow us much capability to expand MATLAB's usefulness. We will start by looking at the help on functions :

```
>>help function
```

We will create our own function that given an input matrix returns a vector containing the admittance matrix(y) of given impedance matrix(z)

```
z= [5 2 4;  
    1 4 5]
```

 as input, the output would be,

```
y= [0.2 0.5 0.25;  
    1 0.25 0.2]
```

 which is the reciprocal of each elements.

To perform the same name the function "admin" and noted that "admin" must be stored in a function M-file named "admin.m". Using an editor, type the following commands and save as "admin.m".

```
function y = admin(z)
    y = 1./z
    return
```

Simply call the function admin from the workspace as follows,

```
>>z=[5 2 4;
      1 4 5]
>>admin(z)
```

The output will be,

```
ans = 0.2 0.5 0.25
      1 0.25 0.2
```

Otherwise the same function can be called for any times from any script file provided the function M-file is available in the current directory. With this introduction anybody can start programming in MATLAB and can be updated themselves by using various commands and functions available. Concerned with the "Power System Simulation Laboratory", initially solve the Power System Problems manually, list the expressions used in the problem and then build your own MATLAB program or function.

### Result:

Thus, the sufficient knowledge about MATLAB to solve power system problems were obtained.

### Outcome:

By doing the experiment, the students can understand the concepts of MATLAB programming in solving power systems problems.

Application:

MATLAB Used

Algorithm development

Scientific and engineering graphics

Modeling, simulation, and prototyping

Application development, including Graphical User Interface building

Math and computation

Data analysis, exploration, and visualization



Viva - voce

1. What is meant by MATLAB?

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

2. What are the different functions used in MATLAB?

The different function `intersect`, `bitshift`, `categorical`, `isfield`

3. What are the different operators used in MATLAB?

Arithmetic, Relational Operations, Logical Operations, Set Operations, Bit-Wise Operations

4. What are the different looping statements used in MATLAB?

For, while

5. What are the different conditional statements used in MATLAB?

If, else

6. What is Simulink?

Simulink, developed by Math Works, is a graphical programming environment for modeling, simulating and analyzing multi domain dynamical systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries.

7. What are the four basic functions to solve Ordinary Differential Equations (ODE)?

`ode45`, `ode15s`, `ode15i`

8. Explain how polynomials can be represented in MATLAB?

`poly`, `polyval`, `polyvalm`, `roots`

9. What is meant by M-file?

An m-file, or script file, is a simple text file where you can place MATLAB commands. When the file is run, MATLAB reads the commands and executes them exactly as it would if you had typed each command sequentially at the MATLAB prompt.

10. What is Interpolation and Extrapolation in MATLAB?

Interpolation in MATLAB is divided into techniques for data points on a grid and scattered data points.

11. List out some of the common toolboxes present in MATLAB?

Control system tool box, power system tool box, communication tool box,

12. What are the MATLAB System Parts?

MATLAB Language, MATLAB working environment, Graphics handler, MATLAB mathematical library, MATLAB Application Program Interface.

13. What are the different applications of MATLAB?

Algorithm development, Scientific and engineering graphics, Modeling, simulation, and prototyping, Application development, including Graphical User Interface building, Math and computation, Data analysis, exploration, and visualization

## **Expt.No.2: COMPUTATION OF TRANSMISSION LINES**

### **PARAMETERS**

#### **Aim:**

To determine the positive sequence line parameters L and C per phase per kilometer of a three phase single and double circuit transmission lines for different conductor arrangements

#### **Software required:**

MATLAB 7.6

#### **Theory:**

Transmission line has four parameters namely resistance, inductance, capacitance and conductance. The inductance and capacitance are due to the effect of magnetic and electric fields around the conductor. The resistance of the conductor is best determined from the manufactures data, the inductances and capacitances can be evaluated using the formula.

#### **Algorithm:**

Step 1: Start the Program

Step 2: Get the input values for distance between the conductors and bundle spacing of

$D_{12}$ ,  $D_{23}$  and  $D_{13}$

Step 3: From the formula given calculate GMD

$GMD = (D_{12} \cdot D_{23} \cdot D_{13})^{1/3}$

Step 4: Calculate the Value of Impedance and Capacitance of the line

Step 5: End the Program

#### **Procedure:**

1. Enter the command window of the MATLAB.
2. Create a new M – file by selecting File - New – M – File
3. Type and save the program in the editor window.
4. Execute the program by either pressing Tools – Run.
5. View the results

#### **Exercise:1**

A three phase transposed line has its conductors placed at a distance of 11 m, 11 m & 22 m. The conductors have a diameter of 3.625cm Calculate the inductance and capacitance of the transposed conductors.

(a) Determine the inductance and capacitance per phase per kilometer of the above three lines.

(b) Verify the results using the MATLAB program.

Calculation:

Inductance:

The general formula:

$$L = 0.2 \ln (D_m / D_s) \text{ mH / Km}$$

Where,

$D_m$  = geometric mean distance (GMD)

$D_s$  = geometric mean radius (GMR)

Single phase 2 wire system:

$$\text{GMD} = D$$

$$\text{GMR} = r' = 0.7788 r$$

Where,  $r$  is the radius of conductor

Three phase – symmetrical spacing :

$$\text{GMD} = D \quad \text{GMR} = r e^{-1/4} = r'$$

Where,  $r$  = radius of conductor &

$$\text{GMR } r' = 0.7788 r$$

Capacitance:

A general formula for evaluating capacitance per phase in micro farad per km of a transmission line is given by,

$$C = 0.0556 / \ln (D_{eq} / r) \mu\text{F/km}$$

Where, GMD is the "Geometric mean distance" which is same as that defined for inductance under various cases.

Program:

```
%3 phase single circuit
D12=input('enter the distance between D12in cm: ');
D23=input('enter the distance between D23in cm: ');
D31=input('enter the distance between D31in cm: ');
d=input('enter the value of d: ');
r=d/2;
Ds=0.7788*r;
x=D12*D23*D31;
Deq=nthroot(x,3);
```

```

Y=log(Deq/Ds);
inductance=0.2*Y
capacitance=0.0556/(log(Deq/r))
fprintf("\n The inductance per phase per km is %f mH/ph/km \n",inductance);
fprintf("\n The capacitance per phase per km is %f mf/ph/km \n",capacitance);
  
```

### Output:

The inductance per phase per km is 1.377882 mH/ph/km

The capacitance per phase per km is 0.008374 mf/ph/km

### Exercise:2

A 345 kV double-circuit three-phase transposed line is composed of two AC SR, 1,431,000-cmil, 45/7 bobolink conductors per phase with vertical conductor configuration as show in figure. The conductors have a diameter of 1.427 inch and a GMR of 0.564 inch. The bundle spacing in 18 inch. Find the inductance and capacitance per phase per Kilometer of the line.

### Calculation:

#### Inductance:

The general formula:

$$L = 0.2 \ln (D_m / D_s) \text{ mH / Km}$$

Where,

$D_m$  = geometric mean distance (GMD)

$D_s$  = geometric mean radius (GMR)

#### Single phase 2 wire system:

$$\text{GMD} = D$$

$$\text{GMR} = r' = 0.7788 r$$

Where,  $r$  is the radius of conductor

#### Three phase – symmetrical spacing :

$$\text{GMD} = D \quad \text{GMR} = r e^{-1/4} = r'$$

Where,  $r$  = radius of conductor &

$$\text{GMR } r' = 0.7788 r$$



### Capacitance:

A general formula for evaluating capacitance per phase in micro farad per km of a transmission line is given by,

$$C = 0.0556 / \ln (D_{eq} / r) \mu F/km$$

Where, GMD is the "Geometric mean distance" which is same as that defined for inductance under various cases.

### Program:

```
%3 phase double circuit
%3 phase double circuit
S = input('Enter row vector [S11, S22, S33] = ');
H = input('Enter row vector [H12, H23] = ');
d = input('Bundle spacing in inch = ');
dia = input('Conductor diameter in inch = '); r=dia/2;
Ds = input('Geometric Mean Radius in inch = ');
S11 = S(1); S22 = S(2); S33 = S(3); H12 = H(1); H23 = H(2);
a1 = -S11/2 + j*H12;
b1 = -S22/2 + j*0;
c1 = -S33/2 - j*H23;
a2 = S11/2 + j*H12;
b2 = S22/2 + j*0;
c2 = S33/2 - j*H23;
Da1b1 = abs(a1 - b1); Da1b2 = abs(a1 - b2);
Da1c1 = abs(a1 - c1); Da1c2 = abs(a1 - c2);
Db1c1 = abs(b1 - c1); Db1c2 = abs(b1 - c2);
Da2b1 = abs(a2 - b1); Da2b2 = abs(a2 - b2);
Da2c1 = abs(a2 - c1); Da2c2 = abs(a2 - c2);
Db2c1 = abs(b2 - c1); Db2c2 = abs(b2 - c2);
Da1a2 = abs(a1 - a2);
Db1b2 = abs(b1 - b2);
Dc1c2 = abs(c1 - c2);
DAB=(Da1b1*Da1b2* Da2b1*Da2b2)^0.25;
DBC=(Db1c1*Db1c2*Db2c1*Db2c2)^.25;
```

```

DCA=(Da1c1*Da1c2*Da2c1*Da2c2)^.25;
GMD=(DAB*DBC*DCA)^(1/3)
Ds = 2.54*Ds/100; r = 2.54*r/100; d = 2.54*d/100;
Dsb = (d*Ds)^(1/2); rb = (d*r)^(1/2);
DSA=sqrt(Dsb*Da1a2);   rA = sqrt(rb*Da1a2);
DSB=sqrt(Dsb*Db1b2);   rB = sqrt(rb*Db1b2);
DSC=sqrt(Dsb*Dc1c2);   rC = sqrt(rb*Dc1c2);
GMRL=(DSA*DSB*DSC)^(1/3)
GMRC = (rA*rB*rC)^(1/3)
L=0.2*log(GMD/GMRL)    % mH/km
C = 0.0556/log(GMD/GMRC) % micro F/km
  
```

### Output of the program:

The inductance per phase per km is 1.377882 mH/ph/km

The capacitance per phase per km is 0.008374 mf/ph/km

### Result:

Thus, the positive sequence line parameters L and C per phase per kilometer of a three phase single and double circuit transmission lines for different conductor arrangements were obtained using MATLAB.

### Outcome:

By doing the experiment, the students can understand the concepts of MATLAB programming in solving parameters of transmission lines.

### Application :

It is used in transmission and distribution of electrical power system.

Viva - voce

1. What is meant by geometric mean distance?

GMD stands for Geometrical Mean Distance. It is the equivalent distance between conductors. GMD comes into picture when there are two or more conductors per phase used as in bundled conductors.

2. What is meant by geometric mean radius?

GMR stands for Geometric mean Radius. GMR is calculated for each phase separately

3. What is meant by transposition of lines?

transposition of transmission line is to rotate the conductors which result in the conductor or a phase being moved to next physical location in a regular sequence. Purpose of Transposition. The transposition arrangement of high voltage lines also helps to reduce the system power loss.

4. What is meant by bundling of conductors?

Mostly long distance power lines are either 220 kV or 400 kV, avoidance of the occurrence of corona is desirable. The high voltage surface gradient is reduced considerably by having two or more conductors per phase in close proximity. This is called Conductor bundling

5. What is meant by double circuit line?

A double-circuit transmission line has two circuits. For three-phase systems, each tower supports and insulates six conductors. Single phase AC-power lines as used for traction current have four conductors for two circuits.

6. What is meant by ACSR conductor?

Aluminium conductor steel-reinforced cable (ACSR) is a type of high-capacity, high-strength stranded conductor typically used in overhead power lines. The outer strands are high-purity aluminium, chosen for its good conductivity, low weight and low cost

7. List out the advantages of bundled conductors.

Bundled conductors are primarily employed to reduce the corona loss and radio interference. However they have several advantages: Bundled conductors per phase reduces the voltage gradient in the vicinity of the line.

8. What is meant by symmetrical spacing?

9. What is meant by skin effect?

Skin effect is a tendency for alternating current (AC) to flow mostly near the outer surface of an electrical conductor, such as metal wire. The effect becomes more and more apparent as the frequency increases.

10. What is meant by proximity effect?

When the conductors carry the high alternating voltage then the currents are non-uniformly distributed on the cross-section area of the conductor. This effect is called proximity effect. The proximity effect results in the increment of the apparent resistance of the conductor due to the presence of the other conductors carrying current in its vicinity.

11. What is meant by Ferranti effect?

In electrical engineering, the Ferranti effect is an increase in voltage occurring at the receiving end of a long transmission line, above the voltage at the sending end. This occurs when the line is energized, but there is a very light load or the load is disconnected.

### Expt.No.3:      **MODELING OF TRANSMISSION LINE**

#### **PARAMETERS**

**Aim:**

To perform the modeling and performance of medium transmission lines

**Software required:**

MATLAB 7.6

**Theory:**

Transmission line has four parameters namely resistance, inductance, capacitance and conductance. The inductance and capacitance are due to the effect of magnetic and electric fields around the conductor. The resistance of the conductor is best determined from the manufactures data, the inductances and capacitances can be evaluated using the formula.

**Formula used:**

**Inductance:**

The general formula:

$$L = 0.2 \ln (D_m / D_s) \text{ mH / Km}$$

Where,

$D_m$  = geometric mean distance (GMD)

$D_s$  = geometric mean radius (GMR)

**Single phase 2 wire system:**

$$\text{GMD} = D$$

$$\text{GMR} = re^{-1/4} = r' = 0.7788 r$$

Where  $r$  is called the radius of conductor

**Three phase – symmetrical spacing:**

$$\text{GMD} = D \quad \text{GMR} = re^{-1/4} = r'$$

Where,  $r$  = radius of conductor &  $\text{GMR} = re^{-1/4} = r' = 0.7788 r$

**Capacitance:**

A general formula for evaluating capacitance per phase in micro farad per km of a transmission line is given by,

$$C = 0.0556 / \ln (D_{eq} / r) \text{ } \mu\text{F/km}$$

Where, GMD is the "Geometric mean distance" which is same as that defined for inductance under various cases.



**Algorithm:**

- Step 1: Start the Program.
- Step 2: Get the input values for conductors.
- Step 3: To find the admittance ( $y$ ) and impedance ( $z$ ).
- Step 4: To find receiving end voltage and receiving end power.
- Step 5: To find receiving end current and sending end voltage and current.
- Step 6: To find the power factor and sending ending power and regulation.

**Procedure:**

1. Enter the command window of the MATLAB.
2. Create a new M – file by selecting File - New – M – File
3. Type and save the program in the editor window.
4. Execute the program by either pressing Tools – Run.
5. View the results

**Result:**

Thus, the modeling and performance of medium transmission lines were obtained using MATLAB.

**Outcome:**

By doing the experiment, the students can understand the concepts of MATLAB programming in solving medium transmission line parameters.

**Application**

It is used in transmission and distribution of electrical power system.

Viva - voce

1. What is meant by regulation?

Regulation is the ratio of no load to full load and no load

2. What are the different types of transmission line?

Single circuit

Double circuit

3. What is meant by efficiency of transmission line?

Transmission line efficiency is the ratio of receiving end power to sending end power.

4. What is meant by nominal  $\pi$  method?

The transmission line analysis with inductor and capacitor arrange in  $\pi$  model.

5. What is meant by nominal T method?

The transmission line analysis with inductor and capacitor arrange in T model.

6. What is the need for different transmission line models?

1. Nominal  $\pi$

2. Nominal T

7. What is meant by surge impedance?

The capacity to withstand the transmission line loading.

## **Expt.No.4: FORMATION OF BUS ADMITTANCE AND IMPEDANCE MATRICES**

### **Aim:**

To determine the bus admittance and impedance matrices for the given power system network

### **Software required:**

MATLAB 7.6

### **Theory:**

#### **Formation of $Y_{bus}$ matrix:**

$Y$ -bus may be formed by inspection method only if there is no mutual coupling between the lines. Every transmission line should be represented by  $\pi$ - equivalent. Shunt impedances are added to diagonal element corresponding to the buses at which these are connected. The off diagonal elements are unaffected. The equivalent circuit of Tap changing transformers is included while forming  $Y$ -bus matrix.

#### **Formation of $Z_{bus}$ matrix:**

In bus impedance matrix the elements on the main diagonal are called driving point impedance and the off-diagonal elements are called the transfer impedance of the buses or nodes. The bus impedance matrix is very useful in fault analysis.

The bus impedance matrix can be determined by two methods. In one method we can form the bus admittance matrix and then taking its inverse to get the bus impedance matrix. In another method, the bus impedance matrix can be directly formed from the reactance diagram and this method requires the knowledge of the modifications of existing bus impedance matrix due to addition of new bus or addition of a new line (or impedance) between existing buses.

### **Algorithm:**

Step 1: Start the program.

Step 2: Enter the bus data matrix in command window.

Step 3: Calculate the values:

$$Y = y_{bus}(\text{busdata})$$

$$Y = y_{bus}(Z)$$

$$Z_{bus} = \text{inv}(Y)$$

Step 4: Form the admittance  $Y_{bus}$  matrix.

Step 5: Form the Impedance  $Z_{bus}$  matrix.

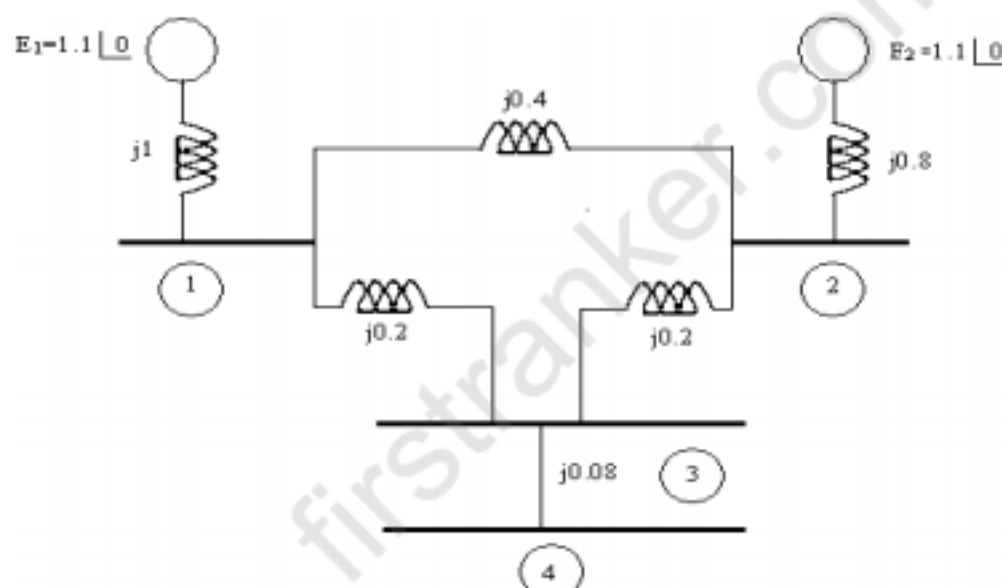
Step 6: End the program.

### Procedure:

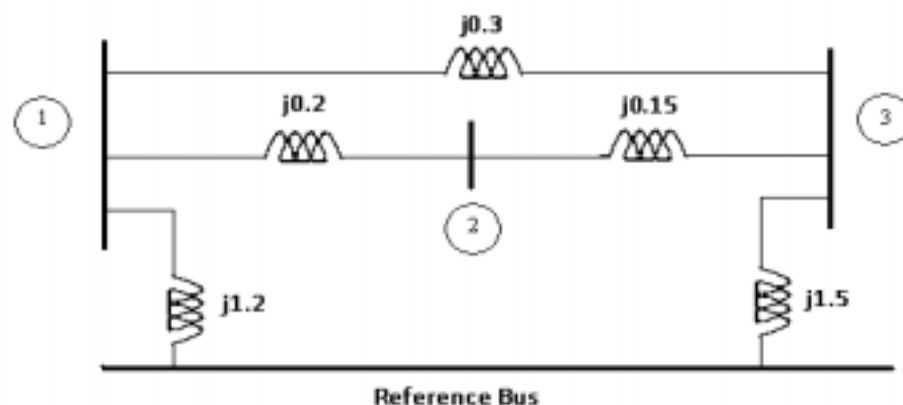
1. Enter the command window of the MATLAB.
2. Create a new M – file by selecting File - New – M – File
3. Type and save the program in the editor window.
4. Execute the program by pressing Tools – Run.
5. View the results.

### Exercise:

- (i) Determine the Y bus matrix for the power system network shown in fig.
- (ii) Check the results obtained in using MATLAB.



2. (i) Determine Z bus matrix for the power system network shown in fig.
- (ii) Check the results obtained using MATLAB.





Line data:

From Bus	To Bus	R	X	B/2
1	2	0.10	0.20	0.02
1	4	0.05	0.20	0.02
1	5	0.08	0.30	0.03
2	3	0.05	0.25	0.03
2	4	0.05	0.10	0.01
2	5	0.10	0.30	0.02
2	6	0.07	0.20	0.025
3	5	0.12	0.26	0.025
3	6	0.02	0.10	0.01
4	5	0.20	0.40	0.04
5	6	0.10	0.30	0.03

Program:

```
% Program to form Admittance and Impedance Bus Formation....
```

```
clc
```

```
fprintf('FORMATION OF BUS ADMITTANCE AND IMPEDANCE MATRIX\n\n')
```

```
fprintf('Enter linedata in order of from bus,to bus,r,x,b\n\n')
```

```
linedata = input('Enter line data : ');
```

```
fb = linedata(:,1); % From bus number...
```

```
tb = linedata(:,2); % To bus number...
```

```
r = linedata(:,3); % Resistance, R...
```

```
x = linedata(:,4); % Reactance, X...
```

```
b = linedata(:,5); % Ground Admittance, B/2...
```

```
z = r + i*x; % Z matrix...
```

```
y = 1./z; % To get inverse of each element...
```

```
b = i*b; % Make B imaginary...
```

```
nbus = max(max(fb),max(tb)); % no. of buses...
```

```
nbranch = length(fb); % no. of branches...
```

```
ybus = zeros(nbus,nbus); % Initialise YBus...
```

% Formation of the Off Diagonal Elements...

for k=1:nbranch

ybus(fb(k),tb(k)) = -y(k);

ybus(tb(k),fb(k)) = ybus(fb(k),tb(k));

end

% Formation of Diagonal Elements....

for m=1:nbus

for n=1:nbranch

if fb(n) == m | tb(n) == m

ybus(m,m) = ybus(m,m) + y(n) + b(n);

end

end

end

ybus = ybus % Bus Admittance Matrix

zbus = inv(ybus); % Bus Impedance Matrix

zbus

### Result:

Thus, the bus admittance and impedance matrices for the given power system network were obtained using MATLAB.

### Outcome:

By doing the experiment, the students can understand the concepts of MATLAB programming in solving bus admittance and impedance matrix.

### Application:

Bus admittance matrix is used for load flow analysis

Bus impedance matrix is used to short circuit study



Viva - voce

1. What is meant by singular transformation method?

The matrix formed by graph theory.

2. What is meant by inspection method?

The admittance matrix calculated directly is called inspection method.

3. What is meant by bus?

Bus is junction point of transmission line.

4. What are the components of a power system?

Generator, Transformer, transmission line, load

5. What is meant by single line diagram?

Power system represented in simple graphical view

6. How are the loads represented in reactance or impedance diagram?

loads represented in reactance diagram resistor with reactor.

7. What are the different methods to solve bus admittance matrix?

Inspection method, direct method

8. What are the elements of the bus admittance matrix?

Reactance

9. What are the elements of the bus impedance matrix?

Resistor and reactor

10. What are the methods available for forming bus impedance matrix?

1. Bus building algorithm

2. using y bus

11. Define per unit value.

Per unit is defined as the ratio of actual value to base value

12. What are the advantages of per unit computations?

The manufacture is used as common value

It is easy to understand.



## **Expt. No. 5: LOAD FREQUENCY DYNAMICS OF SINGLE AREA POWER SYSTEM**

### **Aim:**

To become familiar with modeling and analysis of the frequency and tie-line flow dynamics of a single area power system with and without load frequency controllers (LFC) and to design better controllers for getting better responses

### **Software required:**

MATLAB / SIMULINK

### **Theory:**

Active power control is one of the important control actions to be performed in the normal operation of the system to match the system generation with the continuously changing system load in order to maintain the constancy of system frequency to a fine tolerance level. This is one of the foremost requirements in proving quality of power supply. A change in system load causes a change in the speed of all rotating masses (Turbine – generator rotor systems) of the system leading to change in system frequency. The speed change from synchronous speed initiates the governor control (primary control) action result in the entire participating generator – turbine units taking up the change in load, stabilizing system frequency. Restoration of frequency to nominal value requires secondary control action which adjusts the load - reference set points of selected (regulating) generator – turbine units.

### **Procedure:**

1. Enter the command window of the MATLAB.
2. Create a new Model by selecting File - New – Model.
3. Pick up the blocks from the simulink library browser and form a block diagram.
4. After forming the block diagram, save the block diagram.
5. Double click the scope and view the result.

### **Exercise:**

1. An isolated power station has the following parameters:

Turbine time constant,  $\tau_T = 0.5\text{sec}$ , Governor time constant,  $\tau_g = 0.2\text{sec}$

Generator inertia constant,  $H = 5\text{sec}$ , Governor speed regulation =  $R$  per unit

The load varies by 0.8 percent for a 1 percent change in frequency, i.e,  $D = 0.8$

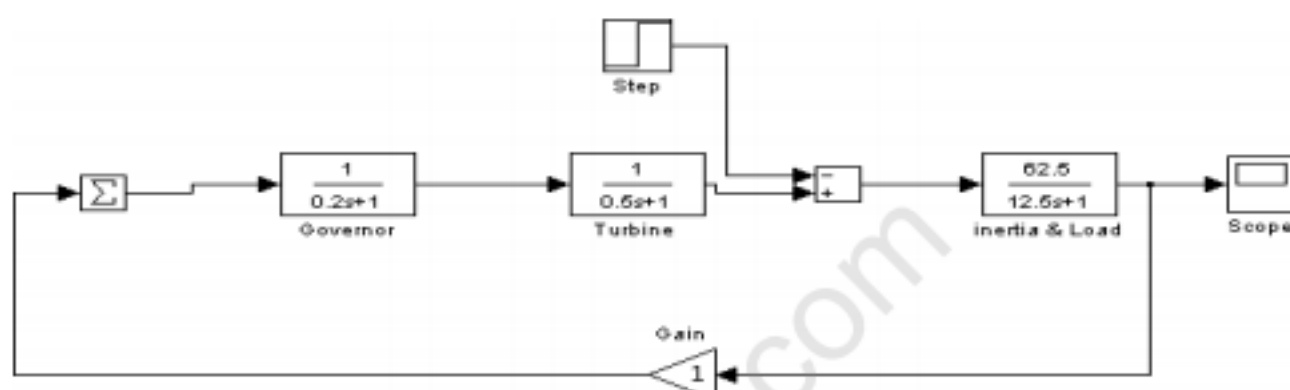
- (a) Use the Routh – Hurwitz array to find the range of  $R$  for control system stability.
- (b) Use MATLAB to obtain the root locus plot.

(c) The governor speed regulation is set to  $R = 0.05$  per unit. The turbine rated output is 250MW at nominal frequency of 60Hz. A sudden load change of 50 MW ( $\Delta P_L = 0.2$  per unit) occurs.

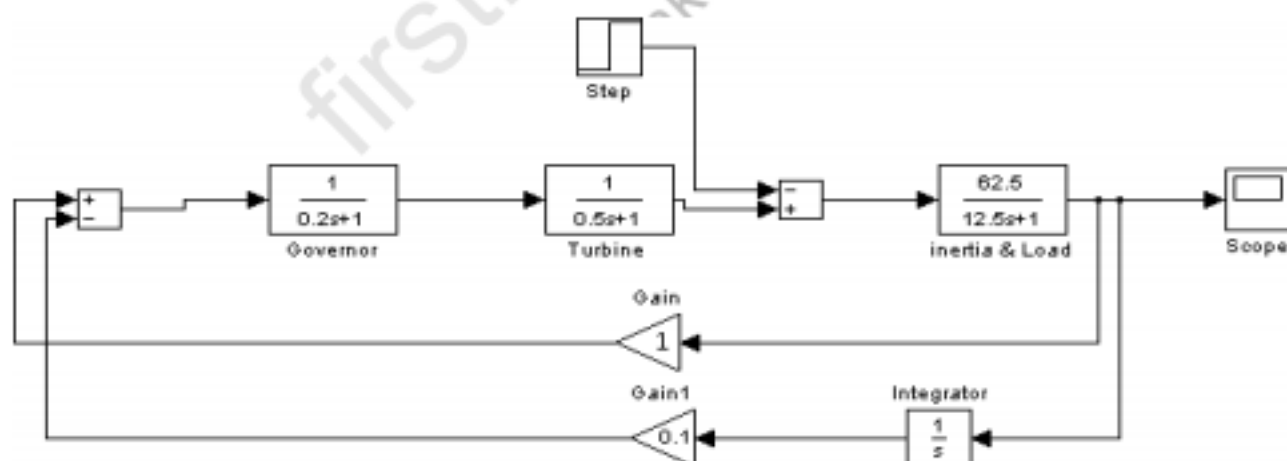
(i) Find the steady state frequency deviation in Hz.

(ii) Use MATLAB to obtain the time domain performance specifications and the frequency deviation step response.

Without integral controller: (simulink block diagram)



With integral controller: (simulink block diagram)



### Exercise: 1

An isolated power system has the following parameter:

Turbine rated output 300 MW, Nominal frequency 50 Hz, Governor speed regulation 2.5 Hz per unit MW, Damping coefficient 0.016 PU MW / Hz, Inertia constant 5 sec, Turbine time constant 0.5 sec, Governor time constant 0.2 s,



Load change 60 MW, The load varies by 0.8 percent for a 1 percent change in frequency, Determine the steady state frequency deviation in Hz

(i) Find the steady state frequency deviation in Hz.

(ii) Use MATLAB to obtain the time domain performance specifications and the frequency deviation step response.

### Exercise: 2

An isolated power system has the following parameter:

Turbine rated output 300 MW, Nominal frequency 50 Hz, Governor speed regulation 2.5 Hz per unit MW, Damping coefficient 0.016 p.u. MW / Hz, Inertia constant 5 sec, Turbine time constant 0.5 sec, Governor time constant 0.2 sec, Load change 60 MW, The system is equipped with secondary integral control loop and the integral controller gain is  $K_I = 1$ . Obtain the frequency deviation for a step response

### Result:

Thus, the modeling and analysis of the frequency and tie-line flow dynamics of a single area power system with and without load frequency controllers (LFC) were obtained using MATLAB/ simulink.

### Outcome:

By doing the experiment, the students can understand the modeling and analysis of the frequency and tie-line flow dynamics of a single area power system with and without load frequency controllers (LFC) using MATLAB/Simulink

### Application:

To maintain the power and frequency constant in electrical power system.

### Viva - voce

1. What is meant by single area system?

If the generation system is considering only one generation unit and one load area it can be treated as a single area system

2. What is meant by load frequency control?

Load frequency control, as the name signifies, regulates the power flow between different areas while holding the frequency constant

3. What is meant by automatic generation control?

In an electric power system, automatic generation control (AGC) is a system for adjusting the power output of multiple generators at different power plants, in response to changes in the load

4. What is meant by speed regulation?

Speed regulation is no load speed to full load speed and no load speed.

5. What is meant by inertia constant?

Inertia constant is "the ratio of kinetic energy of a rotor of a synchronous machine to the rating of a machine



6. What are the major control loops used in large generators?

Primary control loop

Secondary control loop

7. What is the use of secondary loop?

Secondary control loop is used to maintain the frequency as constant.

8. What is the advantage of AVR loop over ALFC loop?

AVR loop is much faster than the ALFC loop and therefore there is a tendency, for the AVR dynamics to settle down before they can make themselves felt in the slower load – frequency control channel.

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## **Expt.No.6: LOAD FREQUENCY DYNAMICS OF TWO AREA POWER SYSTEM**

### **Aim:**

To become familiar with modeling and analysis of the frequency and tie-line flow dynamics of a two area power system without and with load frequency controllers (LFC) and to design better controllers for getting better responses

### **Software required:**

MATLAB / SIMULINK

### **Theory:**

Active power control is one of the important control actions to be performed in the normal operation of the system to match the system generation with the continuously changing system load in order to maintain the constancy of system frequency to a fine tolerance level. This is one of the foremost requirements in providing quality power supply. A change in system load causes a change in the speed of all rotating masses (Turbine – generator rotor systems) of the system leading to change in system frequency. The speed change from synchronous speed initiates the governor control (primary control) action result in the entire participating generator – turbine units taking up the change in load, stabilizing system frequency. Restoration of frequency to nominal value requires secondary control action which adjusts the load - reference set points of selected (regulating) generator – turbine units

### **Procedure:**

1. Enter the command window of the MATLAB
2. Create a new model by selecting File - New – Model
3. Pick up the blocks from the simulink library browser and form a block diagram
4. After forming the block diagram, save the block diagram
5. Double click the scope and view the result

### **Exercise:**

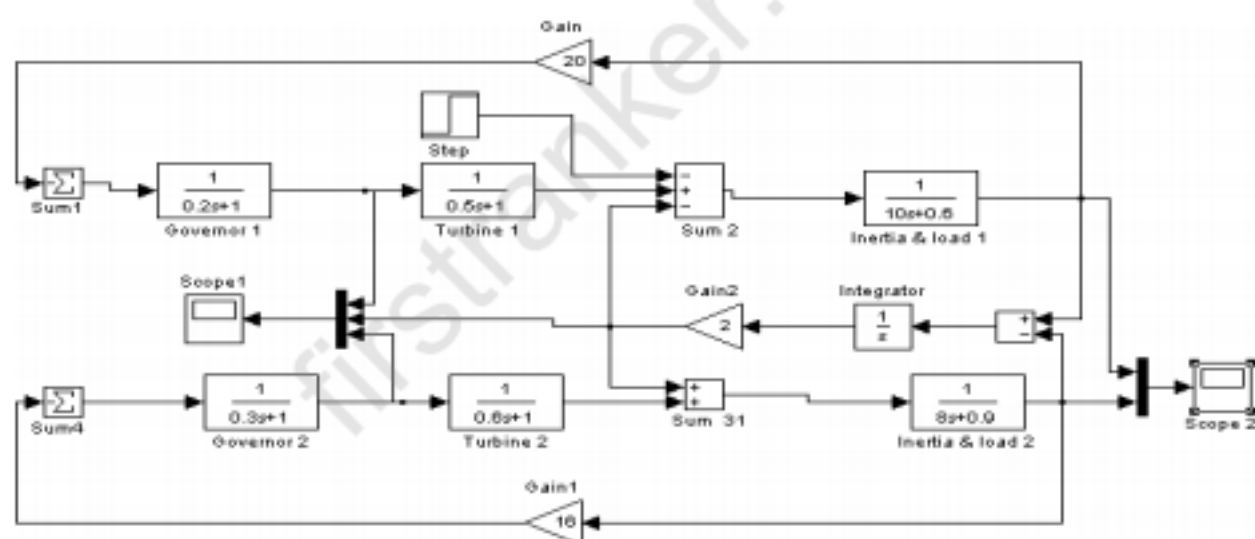
A Two- area system connected by a tie- line has the following parameters on a 1000 MVA common base.

Area	1	2
Speed regulation	$R_1=0.05$	$R_2=0.0625$
damping coefficient	$D_1=0.6$	$D_2=0.9$
Inertia constant	$H_1=5$	$H_2=4$
Base power	1000MVA	1000MVA
Governor time constant	$\tau_{g1} = 0.2\text{sec}$	$\tau_{g1} = 0.3\text{sec}$
Turbine time constant	$\tau_{T1}=0.5\text{sec}$	$\tau_{T1}=0.6\text{sec}$

The units are operating in parallel at the nominal frequency of 60Hz. The synchronizing power coefficient is computed from the initial operating condition and is given to be  $P_s = 2$  p.u. A load change of 187.5 MW occurs in area1.

- Determine the new steady state frequency and the change in the tie-line flow.
- Construct the SIMULINK block diagram and obtain the frequency deviation response for the condition in part (a).

Simulink block diagram:



**Result:**

Thus, the modeling and analysis of the frequency and tie-line flow dynamics of a two area power system with and without load frequency controllers (LFC) were obtained using MATLAB / Simulink.

**Outcome:**

By doing the experiment, the students can understand the modeling and analysis of the frequency and tie-line flow dynamics of a two area power system with and without load frequency controllers (LFC) using MATLAB/Simulink.



Application:

To maintain the power and frequency constant in electrical power system.

Viva - voce

1. What is meant by two area system?  
power system is interconnected one where no of generators are connected together and run in unison manner to meet the demand
2. What is meant by load frequency control?  
Load frequency control, as the name signifies, regulates the power flow between different areas while holding the frequency constant
3. What is meant by area frequency response coefficient?  
a and b
4. What are the major control loops used in large generators?  
Frequency control loop  
Current control loop
5. What is the use of secondary loop?  
Secondary control loop is used to maintain the frequency as constant.





**Expt.No.7: TRANSIENT AND SMALL SIGNAL STABILITY**  
**ANALYSIS OF SINGLE MACHINE INFINITE BUS**  
**SYSTEM**

**Aim:**

To become familiar with various aspects of the transient and small signal stability analysis of Single-Machine-Infinite Bus (SMIB) system

**Software required:**

MATLAB 7.6

**Theory:**

**Transient stability:**

When a power system is under steady state, the load plus transmission loss equals to the generation in the system. The generating units run at synchronous speed and system frequency, voltage, current and power flows are steady. When a large disturbance such as three phase fault, loss of load, loss of generation etc., occurs the power balance is upset and the generating units rotors experience either acceleration or deceleration. The system may come back to a steady state condition maintaining synchronism or it may break into subsystems or one or more machines may pull out of synchronism. In the former case the system is said to be stable and in the later case it is said to be unstable.

**Small signal stability:**

When a power system is under steady state, normal operating condition, the system may be subjected to small disturbances such as variation in load and generation, change in field voltage, change in mechanical torque etc., the nature of system response to small disturbance depends on the operating conditions, the transmission system strength, types of controllers etc. Instability that may result from small disturbance may be of two forms,

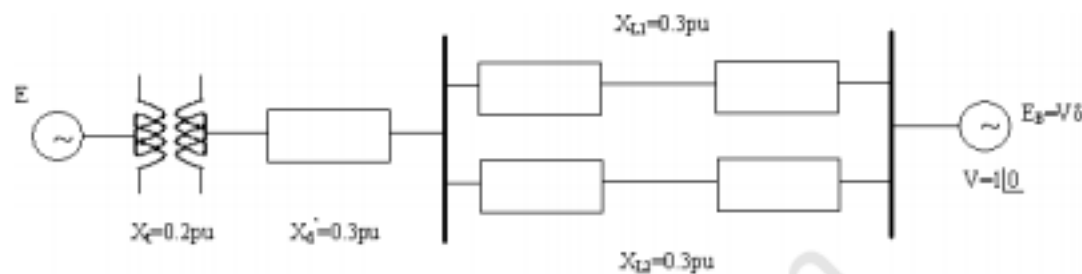
- (a) Steady increase in rotor angle due to lack of synchronizing torque.
- (b) Rotor oscillations of increasing magnitude due to lack of sufficient damping torque.

**Procedure:**

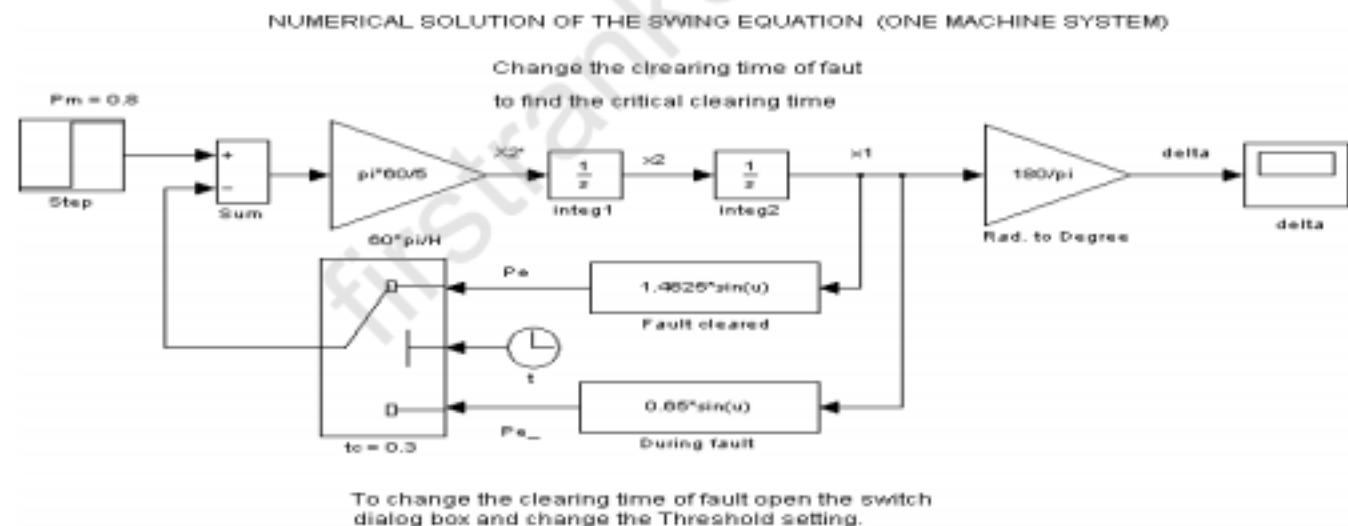
1. Enter the command window of the MATLAB
2. Create a new M – file by selecting File - New – M – File
3. Type and save the program
4. Execute the program by pressing Tools – Run
5. View the results

### Exercise:

A 60Hz synchronous generator having inertia constant  $H = 5$  MJ/MVA and a direct axis transient reactance  $X_d' = 0.3$  per unit is connected to an infinite bus through a purely reactive circuit as shown in figure. Reactance's are marked on the diagram on a common system base. The generator is delivering real power  $P_e = 0.8$  per unit and  $Q = 0.074$  per unit to the infinite bus at a voltage of  $V = 1$  per unit.



- A temporary three-phase fault occurs at the sending end of the line at point F. When the fault is cleared, both lines are intact. Determine the critical clearing angle and the critical fault clearing time.
- Verify the result using MATLAB program



### Result:

Thus, the various aspects of the transient and small signal stability analysis of Single-Machine-Infinite Bus (SMIB) system were analyzed using MATLAB.

### Outcome:

By doing the experiment, the transient and small stability analysis of Single machine Infinite Bus system were analyzed using MATLAB programming

Viva - voce

**1. What is meant by stability?**

Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact

**2. What is meant by transient stability?**

The ability of a synchronous power system to return to stable condition and maintain its synchronism following a relatively large disturbance arising from very general situations like switching ON and OFF of circuit elements, or clearing of faults, etc. is referred to as the transient stability in power system

**3. What is meant by single machine infinite bus?**

The single-machine infinite-bus power system is an approximate representation of a kind of real power systems, where a power plant with a generator or a group of generators are connected by transmission lines to a very large power network

**4. Define –Fault Clearing Time**

The Critical Fault Clearing Time (CFCT) is the most common criteria for evaluation of transient angle stability. The CFCT is the maximum time during which a disturbance can be applied without the system losing its stability

**5. Write the two ways by which transient stability study can be made in a system where one machine is swinging with respect to an infinite bus.****6. Define – Critical Clearing Time**

The Critical Clearing Time is the maximum time during which a disturbance can be applied without the system losing its stability. The aim of this calculation is to determine the characteristics of protections required by the power system.

**7. Define – Critical Clearing Angle**

The critical clearing angle is defined as the maximum change in the load angle curve before clearing the fault without loss of synchronism

**8. What is meant by Equal Area Criterion?**

The Equal area criterion is a "graphical technique used to examine the transient stability of the machine systems (one or more than one) with an infinite bus"

**9. Write the power angle equation and draw the power angle curve.**

A power system consists of a number of synchronous machines operating synchronously under all operating conditions. Under normal operating conditions, the relative position of the rotor axis and the resultant magnetic field axis is fixed. The angle between the two is known as the power angle or torque angle

## **Expt.No.8: ECONOMIC DISPATCH IN POWER SYSTEMS USING MATLAB**

### **Aim:**

To understand the fundamentals of economic dispatch and solve the problem using classical method with and without line losses

### **Software required:**

MATLAB 7.6

### **Theory:**

Mathematical model for economic dispatch of thermal units without transmission loss:

Statement of economic dispatch problem:

In a power system, with negligible transmission loss and with  $N$  number of spinning thermal generating units the total system load  $P_D$  at a particular interval can be met by different sets of generation schedules

$\{PG_1^{(k)}, PG_2^{(k)}, \dots, PG_N^{(k)}\}; \quad k = 1, 2, \dots, N_s$

Out of these  $N_s$  set of generation schedules, the system operator has to choose the set of schedules, which minimize the system operating cost, which is essentially the sum of the production cost of all the generating units. This economic dispatch problem is mathematically stated as an optimization problem.

### **Algorithm:**

- Step 1: Start the program
- Step 2: Get the input values of alpha, beta and gamma
- Step 3: Use the intermediate variable as lambda
- Step 4: Iterate the variables up to feasible solution
- Step 5: To find total cost and economic cost of generator
- Step 6: End the program.

### **Procedure:**

1. Enter the command window of the MATLAB.
2. Create a new M – file by selecting file - new – M – File
3. Type and save the program.
4. Execute the program by either pressing Tools – Run.
5. View the results.

### Exercise 1:

The fuel cost functions for three thermal plants in \$/h are given by

$$C_1 = 500 + 5.3 P_1 + 0.004 P_1^2; \quad P_1 \text{ in MW}$$

$$C_2 = 400 + 5.5 P_2 + 0.006 P_2^2; \quad P_2 \text{ in MW}$$

$$C_3 = 200 + 5.8 P_3 + 0.009 P_3^2; \quad P_3 \text{ in MW}$$

The total load,  $P_D$  is 800MW. Neglecting line losses and generator limits, find the optimal dispatch and the total cost in \$/hr by analytical method. Verify the result using MATLAB program.

### Program:

```
clc;
clear all;
warning off;
a=[.004; .006; .009];
b=[5.3; 5.5; 5.8];
c=[500; 400; 200];
Pd=800;
delp=10;
lambda=input('Enter estimated value of lambda=');
fprintf('\n')
disp(['lambda P1 P2 P3 delta p delta lambda'])
iter=0;
while abs(delp)>=0.001
    iter=iter+1;
    p=(lambda-b)./(2*a);
    delp=Pd-sum(p);
    J=sum(ones(length(a),1)./(2*a));
    dellambda=delp/J;
    disp([lambda,p(1),p(2),p(3),delp,dellambda])
    lambda=lambda+dellambda;
end
lambda
p
```



```
totalcost=sum(c+b.*p+a.*p.^2)
```

Output:

```
Enter estimated value of lambda= 10
lambda P1 P2 P3 delta p delta lambda
10.0000 587.5000 375.0000 233.3333 -395.8333 -1.5000
8.5000 400.0000 250.0000 150.0000 0 0
lambda =
8.5000
p =
400.0000
250.0000
150.0000
Total cost = 6.6825e+003
```

## Exercise 2:

The fuel cost functions for three thermal plants in \$/h are given by

$$C_1 = 500 + 5.3 P_1 + 0.004 P_1^2; \quad P_1 \text{ in MW}$$

$$C_2 = 400 + 5.5 P_2 + 0.006 P_2^2; \quad P_2 \text{ in MW}$$

$$C_3 = 200 + 5.8 P_3 + 0.009 P_3^2; \quad P_3 \text{ in MW}$$

The total load,  $P_D$  is 975MW. The generation limits are:

$$200 \leq P_1 \leq 450 \text{ MW}$$

$$150 \leq P_2 \leq 350 \text{ MW}$$

$$100 \leq P_3 \leq 225 \text{ MW}$$

Find the optimal dispatch and the total cost in \$/h by analytical method. Verify the result using MATLAB program.

Program:

```
clear
clc
n=3;
demand=925;
a=[.0056 .0045 .0079];
b=[4.5 5.2 5.8];
```

```
c=[640 580 820];  
Pmin=[200 250 125];  
Pmax=[350 450 225];  
x=0; y=0;  
for i=1:n  
    x=x+(b(i)/(2*a(i)));  
    y=y+(1/(2*a(i)));  
    lambda=(demand+x)/y  
    Pgtotal=0;  
    for i=1:n  
        Pg(i)=(lambda-b(i))/(2*a(i));  
        Pgtotal=sum(Pg);  
    end  
    Pg  
    for i=1:n  
        if(Pmin(i)<=Pg(i)&&Pg(i)<=Pmax(i));  
            Pg(i);  
        else  
            if(Pg(i)<=Pmin(i))  
                Pg(i)=Pmin(i);  
            else  
                Pg(i)=Pmax(i);  
            end  
        end  
    end  
    Pgtotal=sum(Pg);  
end  
Pg  
if Pgtotal~=demand  
    demandnew=demand-Pg(1)  
    x1=0;  
    y1=0;
```

```

for i=2:n
    x1=x1+(b(i)/(2*a(i)));
    y1=y1+(1/(2*a(i)));
end
lambdanew=(demandnew+x1)/y1
for i=2:n
    Pg(i)=(lambdanew-b(i))/(2*a(i));
end
end
end
Pg

```

Output:

lambda =

8.6149

Pg =

367.4040 379.4361 178.1598

Pg =

350.0000 379.4361 178.1598

Demand new =

575

Lambda new =

8.7147

Pg =

350.0000 390.5242 184.4758

Result:

Thus, the fundamentals of economic dispatch problem using classical method with and without line losses were obtained using MATLAB.

Outcome:

By doing the experiment, the MATLAB programming for economic dispatch problem has been coded for with and without loss conditions.

Application:

Used in power system with lowest cost and schedule with generating unit

**Viva - voce**

1. Define – Economic Dispatch  
Economic dispatch is the short-term determination of the optimal output of a number of electricity generation facilities, to meet the system load, at the lowest possible cost, subject to transmission and operational constraints
2. What is meant by lambda iteration method?  
lambda iteration method is used to calculate economic dispatch.
3. Define – Unit commitment  
Unit Commitment (UC) is the problem of determining the schedule of generating units within a power system subject to device and operating constraints
4. What are the different constraints in unit commitment?  
Fuel constraint, station constraint
5. Compare unit commitment from economic dispatch.  
Schedule of power generating unit  
Operate with lowest price
6. What is the objective of economic dispatch problem?  
objective of economic dispatch is lowest possible cost, subject to transmission and operational constraints
7. What is meant by incremental cost?  
Cost function of economic dispatch
8. What is meant by base point?  
Minimum load Base load in power system
9. What is meant by participation factor?  
Participation factors are scalars intended to measure the relative contribution of system modes to system states, and of system states to system modes, for linear systems

## **Expt.NO.9: TRANSIENT STABILITY ANALYSIS OF MULTI MACHINE INFINITE BUS SYSTEM**

### **Aim:**

To become familiar with various aspects of the transient stability analysis of Multi -Machine-Infinite Bus (MMIB) system

### **Software required:**

MATLAB 7.6

### **Theory:**

#### **Transient stability:**

When a power system is under steady state, the load plus transmission loss equals to the generation in the system. The generating units run at synchronous speed and system frequency, voltage, current and power flows are steady. When a large disturbance such as three phase fault, loss of load, loss of generation etc., occurs the power balance is upset and the generating units rotors experience either acceleration or deceleration. The system may come back to a steady state condition maintaining synchronism or it may break into subsystems or one or more machines may pull out of synchronism. In the former case the system is said to be stable and in the later case it is said to be unstable.

#### **Small signal stability:**

When a power system is under steady state, normal operating condition, the system may be subjected to small disturbances such as variation in load and generation, change in field voltage, change in mechanical torque etc., the nature of system response to small disturbance depends on the operating conditions, the transmission system strength, types of controllers etc. Instability that may result from small disturbance may be of two forms,

1. Steady increase in rotor angle due to lack of synchronizing torque.
2. Rotor oscillations of increasing magnitude due to lack of sufficient damping torque.

#### **Procedure:**

1. Enter the command window of the MATLAB
2. Create a new M – file by selecting File - New – M – File
3. Type and save the program
4. Execute the program by pressing Tools – Run
5. View the results



### Exercise:

1. Transient stability analysis of a 9-bus, 3-machine, 60 Hz power system with the following system modelling requirements:

I. Classical model for all synchronous machines, models for excitation and speed governing systems not included.

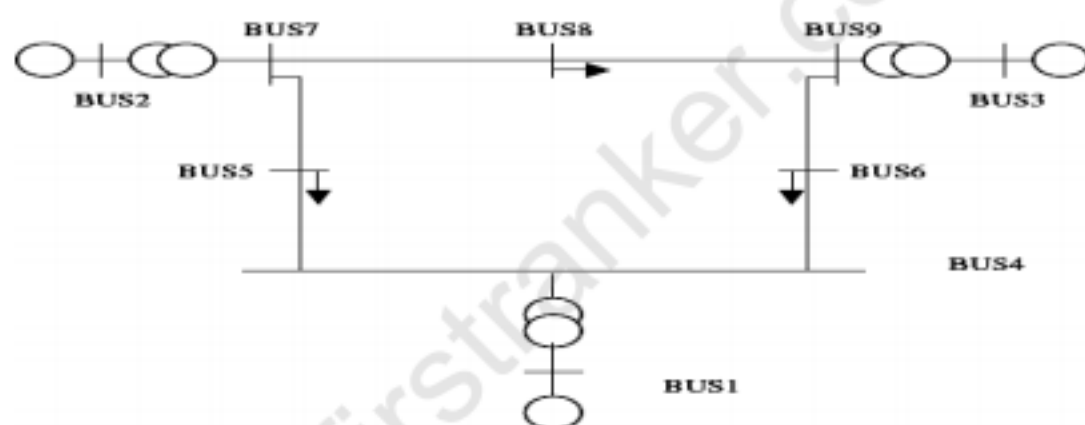
(a) Simulate a three-phase fault at the end of the line from bus 5 to bus 7 near bus 7 at time = 0.0 sec.

Assume that the fault is cleared successfully by opening the line 5-7 after 5 cycles ( 0.083 sec) . Observe the system for 2.0 seconds

(b) Obtain the following time domain plots:

- Relative angles of machines 2 and 3 with respect to machine 1
- Angular speed deviations of machines 1, 2 and 3 from synchronous speed
- Active power variation of machines 1, 2 and 3.

(c) Determine the critical clearing time by progressively increasing the fault clearing time.



### Program:

For (a)

$P_m = 0.8$ ;  $E = 1.17$ ;  $V = 1.0$ ;

$X_1 = 0.65$ ;  $X_2 = \infty$ ;  $X_3 = 0.65$ ;

eacfault (Pm, E, V, X1, X2, X3)

For (b)

$P_m = 0.8$ ;  $E = 1.17$ ;  $V = 1.0$ ;

$X_1 = 0.65$ ;  $X_2 = 1.8$ ;  $X_3 = 0.8$ ;

eacfault (Pm, E, V, X1, X2, X3)

### Result:

Thus, the various aspects of transient stability analysis of Multi -Machine-Infinite Bus (MMIB) system were obtained using MATLAB.

### Outcome:

By doing the experiment, various aspects of transient stability analysis of Multi -Machine-Infinite Bus (MMIB) system were obtained using MATLAB programming

### Application:

Used to analysis to transient and steady state behavior of generator.

**Viva - voce**

1. What is meant by steady state stability?

power system stability as the ability of the power system to return to steady state without losing synchronism.

2. What is meant by small signal stability?

Small-signal stability analysis is about power system stability when subject to small disturbances

3. Write the swing equation in a power system.

$$\frac{2H}{\omega_s} \frac{d^2 \delta}{dt^2} = P_m - P_e = P_a$$

4. Define – Swing Curve

The swing curve is the plot between the power angle and time. It is usually plotted for a transient state to study the nature of variation in angle for a sudden large disturbances

5. Write the simplified power angle equation and the expression for  $P_{max}$ .

$$P_e = P_s = P_R = \frac{V_1 V_2}{X} \sin \delta = P_{max} \sin \delta$$

6. Define – Power Angle

Power angle is the angle between voltage and current, so theoretically it can be defined wherever voltage and current exists

## **Expt.No.10: SOLUTION OF POWER FLOW USING GAUSS-SEIDEL METHOD**

### **Aim:**

To understand, in particular, the mathematical formulation of power flow model in complex form and a simple method of solving power flow problems of small sized system using Gauss-Seidel iterative algorithm

### **Software required:**

MATLAB 7.6

### **Theory:**

The Gauss Siedel method is an iterative algorithm for solving a set of non-linear load flow equations. Power-flow or load-flow studies are important for planning future expansion of power systems as well as in determining the best operation of existing systems. The principal information obtained from the power-flow study is the magnitude and phase angle of the voltage at each bus, and the real and reactive power flowing in each line. Commercial power systems are usually too complex to allow for hand solution of the power flow. Special purpose network analyzers were built between 1929 and the early 1960s to provide laboratory-scale physical models of power systems. Large-scale digital computers replaced the analog methods with numerical solutions. In addition to a power-flow study, computer programs perform related calculations such as short-circuit fault analysis, stability studies (transient & steady-state), unit commitment and economic dispatch.<sup>[1]</sup> In particular, some programs use linear programming to find the optimal power flow, the conditions which give the lowest cost per kilowatt hour deliver.

### **Algorithm:**

Step 1: Start the Program

Step 2: Get the input Value

Step 3: Calculate the  $Y_{bus}$  impedance Matrix

Step 4: Calculate P and Q by using formula,

$$P = \text{Gen MW} - \text{Load MW};$$

$$Q = \text{Gen MVA} - \text{Load MVA};$$

Step 5: Check the condition for the loop

For  $i=2$ : bus and assume  $\sum Y_v=0$

Step 6: Check the condition of for loop

if for  $K=i:n$  bus and check if  $i=k$  and calculate

$$\sum Y_v = \sum Y_v + Y_{bus}(i,k) \cdot V(k)$$

Step 7: Check the condition for type if  $\text{type}(i)=2$ , Calculate  $Q(i)$

$$Q(i) = -\text{imag}(\text{conj}(V(i)) * (\sum Y_v + Y_{\text{bus}}(i,i) * V(i)));$$

Step 8: Check the condition for  $Q(i)$  by using if loop

If  $Q(i) < Q_{\min}(i)$

$Q(i) = Q_{\min}(i)$

Else

$Q(i) = Q_{\max}(i)$

Step 9: Check the condition for type

$$V(i) = 1/Y_{\text{bus}}(i,i) * (P(i) - jQ(i)/\text{Conj}(V(i)) - \sum Y_v);$$

Step 10: Iteration incremented

Step 11: Find the angle value  $\text{angle} = 180/\pi * \text{angle}(v)$

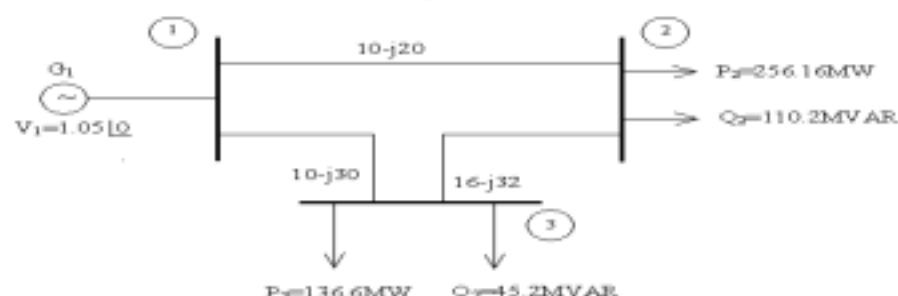
Step 12: End the program

### Procedure:

- 1 Enter the command window of the MATLAB
- 2 Create a new M – file by selecting File - New – M – File.
- 3 Type and save the program in the editor Window
- 4 Execute the program by pressing Tools – Run
- 5 View the results

### Exercise:

The figure shows the single line diagram of a simple 3 bus power system with generator at bus-1. The magnitude at bus 1 is adjusted to 1.05pu. The scheduled loads at buses 2 and 3 are marked on the diagram. Line impedances are marked in p.u. The base value is 100kVA. The line charging susceptances are neglected. Determine the phasor values of the voltage at the load bus 2 and 3. Find the slack bus real and reactive power and verify the results using MATLAB.



Program:

```

clc
clear all
sb=[1 1 2 4 3];          %input('Enter the starting bus = ')
eb=[2 3 4 3 2];          % input('Enter the ending bus = ')
nl=5;                    %input(' Enter the number of lines= ')
nb=4;                    %input(' Enter the number of buses= ')
sa=[1-5j 1.2-4j 1.1-2j 1.2-3j .5-4j]; %input('Enter the value of series impedance =')
Ybus=zeros(nb,nb);
for i=1:nl
    k1=sb(i);
    k2=eb(i) ;
    y(i)=sa(i);
    Ybus(k1,k1)=Ybus(k1,k1)+y(i);%+h(i);
    Ybus(k2,k2)=Ybus(k2,k2)+y(i);%+h(i);
    Ybus(k1,k2)=-y(i);
    Ybus(k2,k1)=Ybus(k1,k2);
end
Ybus
PG=[0 .5 .4 .2];
QG=[0 0 .3j .1j];
V=[1.06 1.04 1 1];
Qmin=.05;
Qmax=.12;
for i=1:nb
    Pg=PG(i);
    Qg=QG(i);
    if(Pg==0&&Qg==0)%for slackbus
        p=1;
        Vt(p)=V(p) ;
    end
    if(Pg~=0&&Qg==0)%for Generator bus
        for q=1:p-1
            A=Ybus(p,q)*V(q);

```



```

end
B=0;
for q=p:nb
    B=B+Ybus(p,q)*V(q);
end
c=V(p)*(A+B);
Q=-imag(c)

if(Qmin<=Q&&Q<=Qmax)%check for Q limit
    Qg=Q*j;
    Vt(p)=V(p);
else
    if(Q<=Qmin)
        Q=Qmin;
    else
        Q=Qmax;
    end
    Vt(p)=1;
    disp('it is load bus')
    Qg=Q*j
end
QG(p)=Qg;
for q=1:p-1
    A1=Ybus(p,q)*V(q);
end
B1=0;
for q=p+1:nb
    B1=B1-((Ybus(p,q))*V(q));
end
C1=((PG(p)-(QG(p)))/Vt(p));
Vt(p)=((C1-A1+B1)/Ybus(p,p));
elseif(Pg~=0&&Qg~=0)%for load bus
    A2=0;
    for q=1:p-1

```

```

    A2=A2-Ybus(p,q)*Vt(q);
end
B2=0;
for q=p+1:nb
    B2=B2-(((Ybus(p,q))*V(q)));
end
C2=(-PG(p)+(QG(p))/V(p));
Vt(p)=((C2+A2+B2)/Ybus(p,p))
end
p=p+1;
end

```

Output:

$Y_{bus} =$

2.2000 - 9.0000i	-1.0000 + 5.0000i	-1.2000 + 4.0000i	0
-1.0000 + 5.0000i	2.6000 -11.0000i	-0.5000 + 4.0000i	-1.1000 + 2.0000i
-1.2000 + 4.0000i	-0.5000 + 4.0000i	2.9000 -11.0000i	-1.2000 + 3.0000i
0	-1.1000 + 2.0000i	-1.2000 + 3.0000i	2.3000 - 5.0000i

$Q =$

0.1456, it is load bus

$Q_g =$

0 + 0.1200i

$V_t =$

1.0600      1.0476 + 0.0397i   1.0061 - 0.0148i   0.9899 - 0.0165i

Result:

Thus, the mathematical formulation of power flow model in complex form and a simple method of solving power flow problems of small sized system using Gauss-Seidel iterative algorithm were obtained using MATLAB.

Outcome:

By doing the experiment, the power flow formulation using Gauss-Seidal algorithm is coded using MATLAB.

Application:

Load flow studies are commonly used to: Optimize component or circuit loading. Develop practical bus voltage profiles

Viva - voce

1. What is meant by load flow analysis?

Load flow studies determine if system voltages remain within specified limits under normal or emergency operating conditions, and whether equipment such as transformers and conductors are overloaded

2. What is meant by acceleration factor?

Gauss-Siedel method has simple calculations and is easy to execute. However, the convergence depends on the acceleration factor

3. Define – Slack Bus

The real power and voltage are specified for buses that are generators. These buses have a constant power generation, controlled through a prime mover, and a constant bus voltage

4. Define – Generator Bus

The real power and voltage are specified for buses that are generators

5. What are the different types of buses in power system network?

Slack Bus, Generator Bus and Load Bus

6. What is meant by acceleration factor in load flow solution? What is its best value?

acceleration factor value 1.6

7. List the advantages of Gauss-Siedal method.

Simplicity in technique

Small computer memory requirement

Less computational time per iteration

8. List the advantages of load flow analysis.

Load flow studies are commonly used to identify real and reactive power flow. Minimize kW and kVar losses

9. What is meant by P-Q bus in power flow analysis?

Load bus is P-Q bus

10. Define – Primitive matrix

$z$  is a square matrix of size  $e \times e$ . The matrix  $z$  is known as primitive impedance matrix.

## **Expt.no.11: SOLUTION OF POWER FLOW USING NEWTON-RAPHSON METHOD**

### **Aim:**

To determine the power flow analysis using Newton – Raphson method

### **Software required:**

MATLAB 7.6

### **Theory:**

The Newton Raphson method of load flow analysis is an iterative method which approximates the set of non-linear simultaneous equations to a set of linear simultaneous equations using Taylor's series expansion and the terms are limited to first order approximation. Power-flow or load-flow studies are important for planning future expansion of power systems as well as in determining the best operation of existing systems. The principal information obtained from the power-flow study is the magnitude and phase angle of the voltage at each bus, and the real and reactive power flowing in each line. Commercial power systems are usually too complex to allow for hand solution of the power flow. Special purpose network analyzers were built between 1929 and the early 1960s to provide laboratory-scale physical models of power systems. Large-scale digital computers replaced the analog methods with numerical solutions. In addition to a power-flow study, computer programs perform related calculations such as short-circuit fault analysis, stability studies (transient & steady-state), unit commitment and economic dispatch.<sup>[1]</sup> In particular, some programs use linear programming to find the optimal power flow, the conditions which give the lowest cost per kilowatt hour deliver.

### **Algorithm:**

Step 1: Start the Program

Step 2: Declare the Variable gbus=6; ybus=6

Step 3: Read the Variable for bus, type, V, de, Pg, Qg, Pl, Ql, Q<sub>min</sub>, Q<sub>max</sub>

Step 4: To calculate P and Q

Step 5: Set for loop for i=1:nbus, for k=1:nbus then calculate

P(i) & Q(i) End the Loop

Step 6: To check the Q limit Violation

Set if iter<=7 && iter>2

Set for n=2: nbus

Calculate Q(G), V(n) for Q<sub>min</sub> or Q<sub>max</sub>

End the Loop

Step 7: Change from specified Value

Declare  $dPa = P_{sp} - P$

$dQa = Q_{sp} - Q$

$dQ = \text{Zeros}(npq, 1)$

Set if  $\text{type}(i) == 3$

End the Loop

Step 8: Find Derivative of Real power injections with angles for Jacobian J1

Step 9: Find Derivative of Reactive power injections with angles for J3

Step 10: Find Derivative of Reactive power injections with voltage for J4 & Real power injections with angles for J2

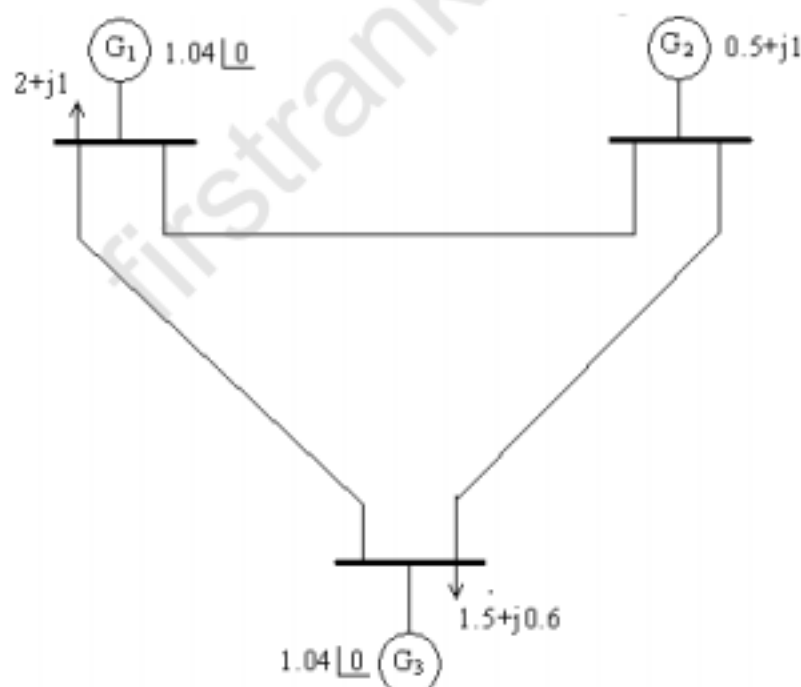
Step 11: Form Jacobian Matrix  $J = [J1 \ J2; J3 \ J4]$

Step 12: Find line current flow & line Losses

Step 13: Display the output

Step 14: End the Program

Exercise:





1. Consider the 3 bus system each of the 3 line bus a series impedance of  $0.02 + j0.08$  p.u and a total shunt admittance of  $j0.02$  p.u. The specified quantities at the bus are given below.

Bus	Real load demand, $P_D$	Reactive Load demand, $Q_D$	Real power Generation, $P_G$	Reactive Power Generation, $Q_G$	Voltage Specified
1	2	1	-	-	$V_1=1.04$
2	0	0	0.5	1	Unspecified
3	1.5	0.6	0	$Q_{G3} = ?$	$V_3 = 1.04$

2. Verify the result using MATLAB

### Program:

```
%NEWTON RAPHSON METHOD
```

```
clc
```

```
clear all
```

```
sb=[1 1 2]; %input('Enter the starting bus =')
```

```
eb=[2 3 3]; % input('Enter the ending bus =')
```

```
nl=3; %input(' Enter the number of lines=')
```

```
nb=3; %input(' Enter the number of buses=')
```

```
sa=[1.25-3.75j 5-15j 1.667-5j]; %input('Enter the value of series impedance =')
```

```
Ybus=zeros(nb,nb);
```

```
for i=1:nl
```

```
    k1=sb(i);
```

```
    k2=eb(i);
```

```
    y(i)=(sa(i));
```

```
    Ybus(k1,k1)=Ybus(k1,k1)+y(i);
```

```
    Ybus(k2,k2)=Ybus(k2,k2)+y(i);
```

```
    Ybus(k1,k2)=-y(i);
```

```
    Ybus(k2,k1)=Ybus(k1,k2);
```

```
end
```

```
Ybus
```

```
Ybusmag=abs(Ybus);
```

```
Ybusang=angle(Ybus)*(180/pi);
```

```
% Calculation of P and Q
```

```
v=[1.06 1 1];
```

```

P=[0 0 0];
Q=[0 0 0];
del=[0 0 0];
Pg=[0 0.2 0];
Pd=[0 0 0.6];
Qg=[0 0 0];
Qd=[0 0 0.25];
for p=2:nb
    for q=1:nb
        P(p)=P(p)+(v(p)*v(q)*Ybusmag(p,q)*cos(del(p)+angle(Ybus(p,q))-del(q)));
        Q(p)=(Q(p)+(v(p)*v(q)*Ybusmag(p,q)*sin(del(p)-angle(Ybus(p,q))-del(q))));
        Pspe(p)=Pg(p)-Pd(p);
        Qspe(p)=Qg(p)-Qd(p);
        delP(p)=Pspe(p)-P(p);
        delQ(p)=Qspe(p)-Q(p);
    end
end
P;
Q;
Pspe;
Qspe;
delP;
delQ;

```

%Calculation of J1

```

P2=[0 0 0];
for p=2:nb
    for q=2:nb
        if(p==q)
            P1=2*v(p)*Ybusmag(p,q)*cos(angle(Ybus(p,q)));
            for j=1:nb
                if (j~=p)
                    P2(q)=P2(q)+v(j)*Ybusmag(q,j)*cos(del(q)+angle(Ybus(q,j))-del(j));
                    PV(p,q)=P1+P2(q);
                end
            end
        end
    end
end

```

```

        end
    end
else
    PV(p,q)=v(p)*Ybusmag(p,q)*cos(del(p)+angle(Ybus(p,q))-del(q));
end
end
end
PV;
% Calculation of J2
Pdel=[0 0 0;0 0 0;0 0 0];
for p=2:nb
    for q=2:nb
        if(p==q)
            for j=1:nb
                if(j~=p)
                    Pdel(p,q)=Pdel(p,q)-v(j)*v(q)*Ybusmag(q,j)*sin(del(q)-angle(Ybus(p,j))-del(j));
                end
            end
        else
            Pdel(p,q)=-v(p)*v(q)*Ybusmag(p,q)*sin(del(p)+angle(Ybus(p,q))-del(q));
        end
    end
end
Pdel;
%Calculation of J3
Q2=[0 0 0];
for p=2:nb
    for q=2:nb
        if(p==q)
            Q1=2*v(p)*Ybusmag(p,q)*sin(-angle(Ybus(p,q)));
        end
        for j=1:nb
            if (j~=p)
                Q2(q)=Q2(q)+v(j)*Ybusmag(q,j)*sin(del(q)-angle(Ybus(q,j))-del(j));
            end
        end
        QV(p,q)=Q1+Q2(q);
    end
end

```

```

        end
    end
else
    QV(p,q)=v(p)*Ybusmag(p,q)*sin(del(p)-angle(Ybus(p,q))-del(q));
end
end

end
QV;
%Calculation of J4
Qdel=[0 0 0;0 0 0;0 0 0];
for p=2:nb
    for q=2:nb
        if(p==q)
            for j=1:nb
                if(j~=p)
                    Qdel(p,q)=Qdel(p,q)+v(j)*v(q)*Ybusmag(q,j)*cos(del(q)+angle(Ybus(p,j))-del(j));
                end
            end
        else
            Qdel(p,q)=-v(p)*v(q)*Ybusmag(p,q)*cos(del(p)+angle(Ybus(p,q))-del(q));
        end
    end
end
end
Qdel;
%Jacobian matrix
PV(1,:)=[];
PV(:,1)=[];
Pdel(1,:)=[];
Pdel(:,1)=[];
QV(1,:)=[];
QV(:,1)=[];
Qdel(1,:)=[];
Qdel(:,1)=[];

```

```
J=[PV Pdel;QV Qdel]
%Find the change in v&del
delP(1:1)=[];
delQ(1:1)=[];
delpq=[delP';delQ']
vdel=inv(J)*delpq
%Find new v&del
for i=1:nb-1
    for j=2:nb
        vnew(i)=v(j)+vdel(i);
        delnew(i)=del(j)+vdel(i+2);
    end
end
VNEW=[v(1) vnew]
DELNEW=[del(1) delnew]
```

Output:

```
Ybus =
    6.2500 -18.7500i   -1.2500 + 3.7500i   -5.0000 +15.0000i
   -1.2500 + 3.7500i    2.9170 - 8.7500i   -1.6670 + 5.0000i
   -5.0000 +15.0000i   -1.6670 + 5.0000i    6.6670 -20.0000i

J =
    2.8420   -1.6670    8.9750   -5.0000
   -1.6670    6.3670   -5.0000   20.9000
    8.5250   -5.0000   -2.9920    1.6670
   -5.0000   19.1000    1.6670   -6.9670

delpq =
    0.2750
   -0.3000
    0.2250
    0.6500

vdel =
    0.0575
    0.0410
    0.0088
```



-0.0201

VNEW =

1.0600 1.0575 1.0410

DELNEW =

0 0.0088 -0.0201

### Result:

Thus, the mathematical formulation of power flow model in complex form and for solving power flow problems of small sized system using Newton Raphson iterative algorithm were obtained using MATLAB.

### Outcome:

By doing the experiment, the power flow formulation using Newton- Raphson algorithm is coded using MATLAB.

### Application:

The Newton-Raphson method was applied to solve the thermal EHD lubrication model of line contacts. By accounting for thermal effects in the Newton-Raphson scheme, a very stable numerical approach was obtained. Two models with viscosity constant and variable across the oil film were developed.

### Viva - voce

1. What is meant by jacobian matrix?

Jacobian matrix is the matrix of all first-order partial derivatives of a vector-valued function. When the matrix is a square matrix, both the matrix

2. What are the different types of buses in power system network?

Slack bus, generator bus and load bus

3. What are the information obtained from a load flow study?

The principal information obtained from the power-flow study is the magnitude and phase angle of the voltage at each bus, and the real and reactive power flowing in each line. Commercial power systems are usually too complex to allow for hand solution of the power flow.

4. What is the need for load flow study?

Load flow studies determine if system voltages remain within specified limits under normal or emergency operating conditions, and whether equipment such as transformers and conductors are overloaded. Load flow studies are commonly used to: Optimize component or circuit loading. Develop practical bus voltage profiles

5. What are the quantities associated with each bus in a system?

P,Q,V, $\delta$

6. Define - Voltage Controlled Bus

Voltage Controlled buses where generators are connected. Therefore the power generation in such buses is controlled through a prime mover while the terminal voltage is controlled through the generator excitation

7. What is the need for slack bus?



The slack bus is the only bus for which the system reference phase angle is defined. From this, the various angular differences can be calculated in the power flow equations. If a slack bus is not specified, then a generator bus with maximum real power.

8. What is meant by flat voltage start?

The value of flat voltage start  $1+j0$

9. What are the advantages of Newton Raphson method?

Newton Raphson method needs less number of iterations to reach convergence, takes less computation time

More accurate and not sensitive to the factors such like slack bus selection, regulation transformers etc. and the number of iterations required in this method is almost independent of system size.

10. What are the disadvantages of Newton Raphson method?

More calculations involved in each iteration and require large computation time per iteration and large computer memory

Difficult solution technique (programming is difficult)



**Expt.No.12: FAULT ANALYSIS IN POWER SYSTEM****Aim:**

To become familiar with modeling and analysis of power systems under faulted condition and to compute the fault level, post-fault voltages and currents for different types of faults, both symmetric and unsymmetrical. To calculate the fault current, post fault voltage and fault current through the branches for a three phase to ground fault in a small power system and also study the effect of neighboring system. Check the results using available software. To obtain the fault current, fault MVA, Post-fault bus voltages and fault current distribution for single line to ground fault, line-to-line fault and double line to ground fault for a small power system, using the available software. To Carryout fault analysis for a sample power system for LLLG, LG, LL and LLG faults and prepare the report

**Software required:**

MATLAB 7.6

**Theory:**

Short circuit studies are performed to determine bus voltages and currents flowing in different parts the system when it is subjected to a fault. The current flowing immediately after the fault consists of an AC component which eventually reaches steady state and a fast decaying DC component which decays to zero. Only the AC component is considered in the analysis. The analysis is done using phasor technique assuming the system to be under quasi-steady state and is done for various types of faults such as three-phase-to ground, line-to-ground, line-to-line and double-line-to-ground. The results of fault studies are used to select the circuit breakers, set protective relays and to assess the voltage dips during fault. It is one of the primary studies to be performed whenever system expansion is planned.

**Modeling details:****Approximations:**

The following approximations are usually made in fault analysis:

1. Pre-fault load currents are neglected
2. Transformer taps are assumed to be nominal
3. A symmetric three phase power system is considered
4. Transmission line shunt capacitance and transformer magnetizing impedances are ignored
5. Series resistances of transmission lines are neglected
6. The negative sequence impedance of alternators is assumed to be the same as their positive sequence impedance

In the case of symmetrical faults, it is sufficient to determine the currents and voltages in one phase. Hence the analysis is carried out on per phase basis (using + ve sequence Impedance network). In the case of unsymmetrical faults, the method of symmetrical components is used.

### Sequence impedances of power system components:

The sequence impedances of power system components namely generators, transmission lines and transformers are required for modeling and analysis of unsymmetrical faults. In the case of overhead transmission lines the positive-and negative-sequence impedances are the same and the zero sequence impedance depends on ground wire, tower footing resistance and grounding adopted.

In the case of transformers, the positive-and negative- sequence impedances are the same and the zero sequence impedance depends on transformer winding connection, method of neutral grounding and transformer type (shell or core). The positive-, negative-and zero-sequence impedances are different in the case of rotating equipment like synchronous generator, synchronous motor and induction motors. Estimation of sequence impedances of the components and assembling of zero-, positive-and negative-sequence impedance networks are the major steps in unsymmetrical fault analysis.

### Short circuit computation:

### Symmetrical fault analysis:

Since the fault is symmetric the analysis is carried out on per phase basis. A short circuit represents a structural change in the network which is equivalent to the addition of impedance (in the case of a symmetric short, three equal impedances) at the location of fault. The changes in voltages and currents that result from this structural change can be analyzed using Thevenin's theorem which states: The changes that occur in the network voltages and currents due to the addition of an impedance between two network nodes are identical with those voltages and currents that would be caused by an emf placed in series with the impedance and having a magnitude and polarity equal to the pre-fault voltage that existed between the nodes in question and all other sources being zeroed. The post-fault voltages and currents in the network are obtained by superposing these changes on the pre-fault voltages and currents.

### Example1:

For the two-bus system shown in Fig .1, determine the fault current at the fault point and in other elements for a fault at bus 2 with a fault impedance  $Z_f$ . Load current can be assumed to be negligible. The pre-fault voltages at all the buses can be assumed to be 1.0 p.u. The sub transient reactance of the generators and positive sequence reactance of other elements are given. Assume that the resistances of all the elements are negligible.



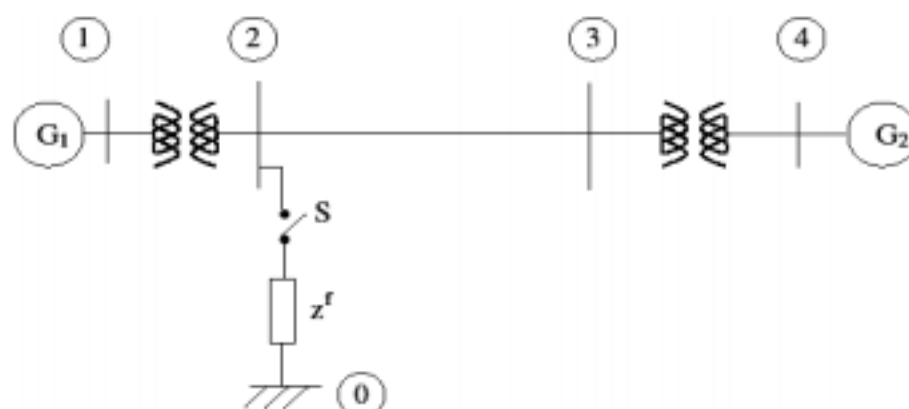


Fig 1 Symmetrical fault on a two bus system

First the "Thevenin's equivalent network" is formed Fig. 2a). The pre-fault voltage at bus2,  $V_{02}$  equals 1.0 p.u. In Fig 2a) the "Thevenin's emf"  $E_{th} = V_{02} = 1.0$  is inserted in series with the short-circuit branch. The reduced Thevenin's equivalent circuit is given in Fig 2c). In which the "Thevenin's equivalent impedance"  $Z_{th}$  is found to be  $j0.144$ p.u. It should be noted that  $Z_{th}$  is nothing but the driving point impedance at bus 2 which is the same as the diagonal element  $Z_{22}$  of bus impedance matrix of the network. With reference to Fig 2c). The fault current is given by

$$I_f = E_{th} / (Z_{th} + z^f)$$

Assuming "solid fault", that is  $z^f = 0$ , the fault current is

$$I_f = 1/j0.144 = 6.94 \angle -90^\circ \text{ per unit}$$

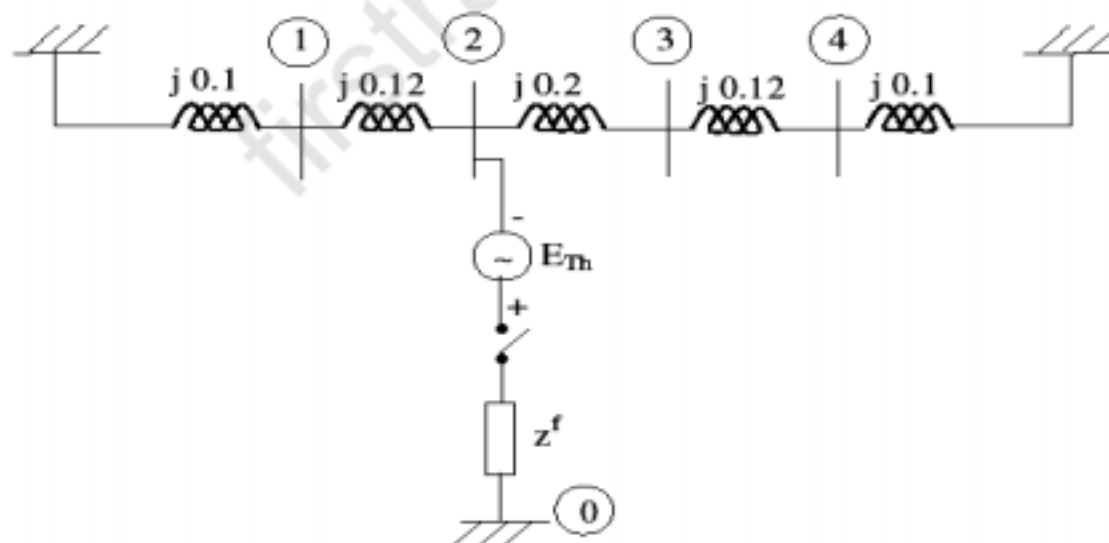


Fig. 2a)



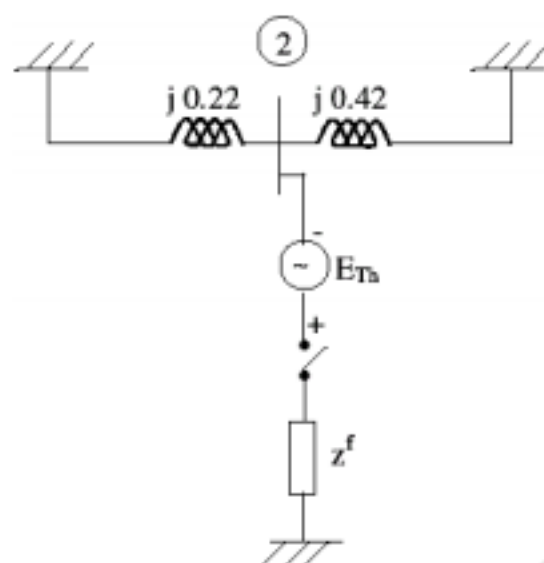


Fig. 2b)

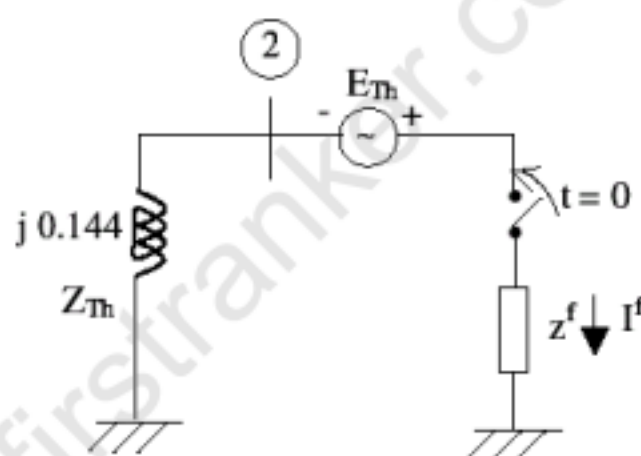


Fig. 2c) Development of thevenin's equivalent circuit (all impedances are in per unit)

This current is the total fault current fed by both the generators. The contribution from each generator can be computed by noting that the total current divides in inverse impedance ratio.

### Interconnections with neighboring systems:

If a power system A, is interconnected to a neighboring system B, through, say a tie-line  $T_{12}$ , then for a fault at any of the buses in system A all the generators in system B also will feed the fault through the tie-line. Instead of representing the complete network of the system B, the Thevenin's equivalent circuit of system B can be connected at the tie bus 2, (Fig 5.3).

The Thevenin's equivalent reactance at bus 2 is given by

$$X_{Th, B} = 1/SCC_2$$

Where  $SCC_2$  is the fault level of Bus2.

Thevenin's source  $E_{Th, B}$  may be assumed as 1.0 p.u

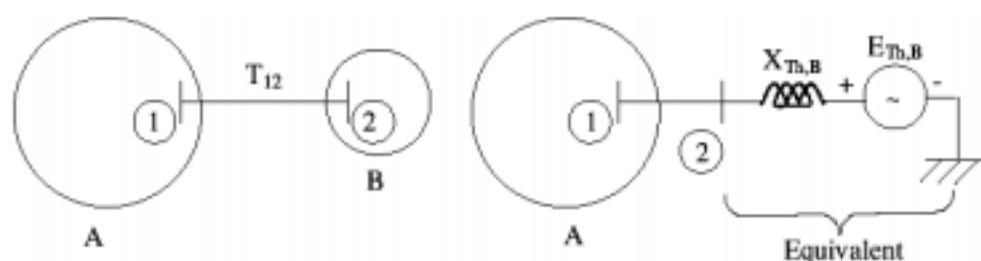


Fig. 3 Thevenin's equivalent for neighboring system

### Systematic computation for large scale systems:

The systematic computation procedure to be used for fault analysis of a large power systems using computer is explained below. Let us consider a symmetric fault at bus  $r$  of an  $n$ -bus system. Let us assume that the pre-fault currents are negligible.

Step: 1

Draw the pre-fault per phase network of the system (positive sequence network) (Fig 5.4). Obtain the positive sequence bus impedance matrix  $Z$  using Building Algorithm. All the machine reactance should be included in the  $Z$  bus.

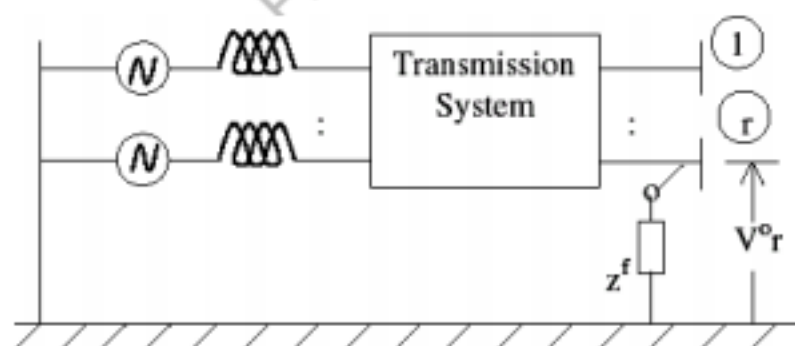


Fig 4 Pre-fault per phase network (with loads neglected)

**Step: 2**

Obtain the fault current using the Thevenin's equivalent of the system feeding the fault as explained below. Assume fault impedance as  $Z^f$ . Thevenin's equivalent of the system feeding the fault impedance is given in figure 5.5.

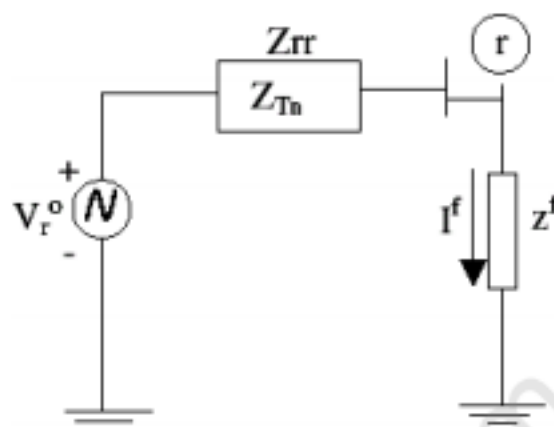


Fig.5 Thevenin's Equivalent of the system feeding the fault

**Step: 3**

Obtain the Thevenin's Equivalent network

**Result:**

Thus, the modeling and analysis of power systems under faulted condition and to compute the fault level, post-fault voltages and currents for different types of faults were obtained using MATLAB.

**Outcome:**

By doing the experiment, the fault analysis in power system has been done using MATLAB and different types of faults have been solved using MATLAB.

**Application:**

Short Circuit Analysis is performed to determine the currents that flow in a power system under fault conditions. A Short Circuit Analysis will help to ensure that personnel and equipment are protected by establishing proper interrupting ratings of protective devices

**Viva - voce**

1. What is meant by fault?  
In an electric power system, a fault or fault current is any abnormal electric current. For example, a short circuit is a fault in which current bypasses the normal load.
2. What are the different types of fault?  
LG, LL, LLG and symmetrical fault



3. What are the assumptions made in fault analysis?

Transformers are on nominal tap position. This will let us take nominal voltages of transformers in calculations.

All sources are balanced and equal in magnitude and phase. We neglect the slight differences in magnitude and phase of the source voltages as it is nothing when compared with the fault.

4. What is meant by bolted fault?

Bolted fault. Notionally, all the conductors are considered connected to ground as if by a metallic conductor; this is called a "bolted fault"

5. What are the different sequence networks in power system?

Positive sequence, negative sequence and zero sequence

6. Why does fault occur in a power system?

An open-circuit fault occurs if a circuit is interrupted by some failure. ... In a "ground fault" or "earth fault", current flows into the earth

7. How are the faults classified?

Symmetrical and unsymmetrical fault

8. List out the various types of shunt and series faults.

Open conductor fault and symmetrical fault



## **Expt.No.13: MODELING OF FACTS DEVICES USING**

### **SIMULINK**

#### **Aim:**

To simulate Facts device in order to control the reactive power flow in a line for efficient operation of the power system and transmission network

#### **Software required:**

MATLAB /SIMULINK

#### **Theory:**

Today's power grids are driven closer to their transfer capacities due to the increased consumption and power transfers, endangering the security of the system. Flexible AC transmission systems (FACTS) have gained a great interest during the last few years, due to recent advances in power electronics. On the other hand, FACTS devices are a powerful technology that can solve many outstanding problems in power systems. FACTS devices have been mainly used for solving various power system steady state control problems such as voltage regulation, power flow control, and transfer capability enhancement. e.g. by improving the voltage profile or increasing the transfer capacity of a system without the need of new lines Generally, it is not cost-effective to install FACTS devices for the sole purpose of power system stability enhancement.

#### **Overview:**

There are two generations for realization of power electronics-based FACTS controllers: the first generation employs conventional thyristor-switched capacitors and reactors, and quadrature tap-changing transformers, the second generation employs gate turn-off (GTO) thyristor-switched converters as voltage source converters (VSC's). The thyristor-controlled group employs capacitor and reactor banks with fast solid-state switches in traditional shunt or series circuit arrangements. The thyristor switches control the on and off periods of the fixed capacitor and reactor banks and thereby realize a variable reactive impedance. Except for losses, they cannot exchange real power with the system. The voltage source converter (VSC) type FACTS controller group employs self-commutated DC to AC converters, using GTO thyristors, which can internally generate capacitive and inductive reactive power for transmission line compensation, without the use of capacitor or reactor banks. The converter with energy storage device can also exchange real power with the system, in addition to the independently controllable reactive power. The VSC can be used uniformly to control transmission line voltage, impedance, and angle by providing reactive shunt compensation, series compensation, and phase shifting, or to control directly the real and reactive power flow in the line.



### Series compensation:

In series compensation, the FACTS is connected in series with the power system. It works as a controllable voltage source. Series inductance occurs in long transmission lines, and when a large current flow causes a large voltage drop. To compensate, series capacitors are connected.

### Shunt compensation:

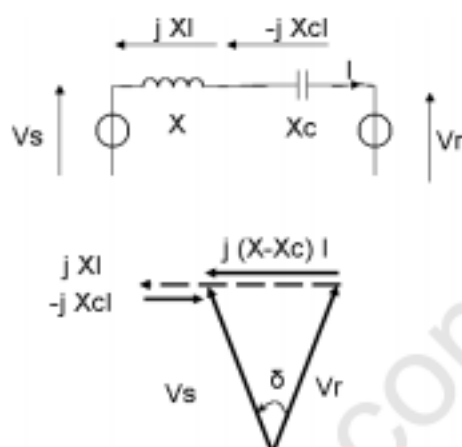


Fig 1. Series Compensation

In shunt compensation, power system is connected in shunt (parallel) with the FACTS. It works as a controllable current source.

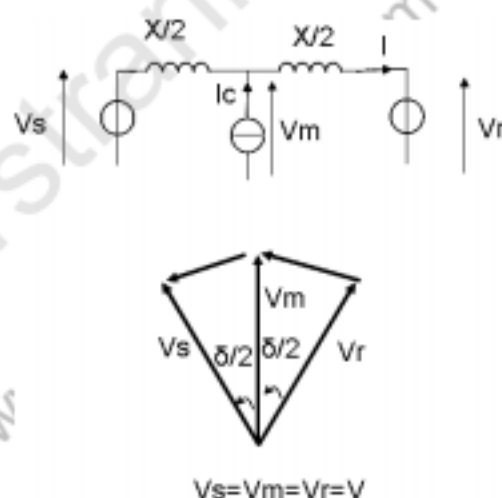


Fig 2. Shunt Compensation

### First generation of Facts devices:

1. Static VAR Compensator (SVC)
2. Thyristor-Controlled Series Capacitor (TCSC)

3. Thyristor-Controlled Phase Shifter (TCPS)

Second generation of Facts devices:

1. Static Compensator (STATCOM)
2. Static Synchronous Series Compensator (SSSC)
3. Unified Power Flow Controller (UPFC)

Series compensation:

FACTS for series compensation modify line impedance:  $X$  is decreased so as to increase the transmittable active power. However, more reactive power must be provided.

$$P = \frac{V^2}{X - X_c} \sin(\delta)$$

$$Q = \frac{V^2}{X - X_c} (1 - \cos \delta)$$

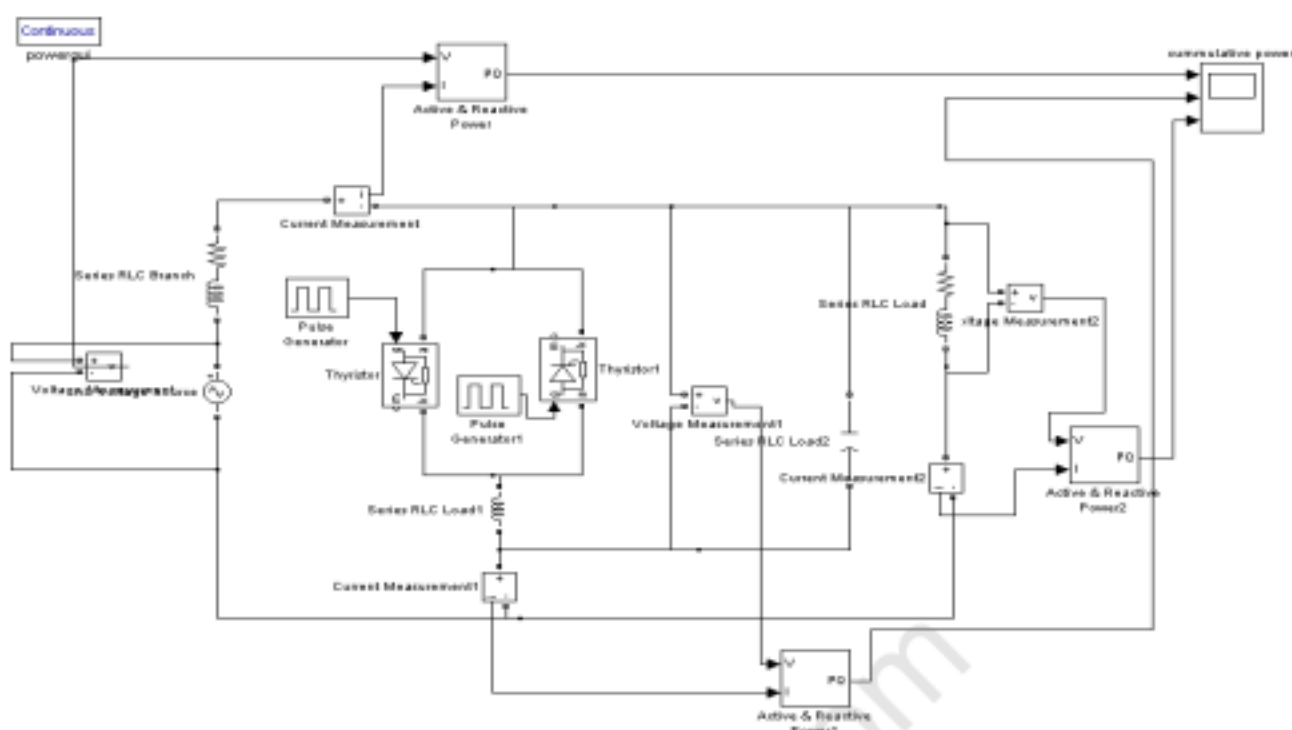
Shunt compensation:

Reactive current is injected into the line to maintain voltage magnitude. Transmittable active power is increased but more reactive power is to be provided.

$$P = \frac{2V^2}{X} \sin\left(\frac{\delta}{2}\right)$$

$$Q = \frac{2V^2}{X} \left[1 - \cos\left(\frac{\delta}{2}\right)\right]$$

Simulink block diagram:



Output:



Result:

Thus, simulation of facts device in order to control the reactive power flow in a line for efficient operation of the power system and transmission network were obtained using MATLAB/simulink.

**Outcome:**

By doing the experiment, the modeling of Facts devices using MATLAB / Simulink has been done.

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