

Shri Ramdeobaba College of Engineering and Management, Nagpur (MS)

(An Autonomous Institution Permanently affiliated to Rashtrasant Tukadoji Maharaj Nagpur University) An ISO 9001:2015 Certified Institution. NAAC Certified 'A' Grade

Department of Electrical Engineering Laboratory Manual

Power Systems II Laboratory

EEP 371

(VI Semester Electrical)

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Vision

Department of Electrical Engineering endeavours to be one of the best departments in India having expertise to mould the students to cater the needs of society in the field of technology, leadership, administration, ethical and social.

Mission

To provide dynamic and scholarly environment for students to achieve excellence in core electrical and multidisciplinary fields by synergetic efforts of all stake holders of the Electrical Engineering Department and inculcate the ethical and social values.

Programme Educational Objectives (PEOs)

PEO 1. Our graduates will be able to plan, design, operate and practice in electrical and energy systems.

PEO 2. Our graduates will be able to work in multidisciplinary environments including IT applications and adapt themselves as per the emerging technological needs of Industry. **PEO 3.** Our graduates will be able to progress in their career by demonstrating in practice the technical and communication skills effectively with understanding of ethical and social values

Program Outcomes and Program Specific Outcomes (UG)

Our electrical engineering graduates will be able to:

PO1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals to the solution of engineering problems.

PO2. **Problem analysis**: Identify, formulate, review literature, and analyze complex engineering problems using first principles of mathematics, natural sciences, and engineering sciences.

PO3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public safety, societal and environmental considerations.

PO4. **Conduct problem investigations**: Use research-based knowledge including experimentation, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. **Modern tool usage**: Select, and apply appropriate techniques, resources, and modern engineering and IT tools for analyzing the engineering activities with an understanding of the limitations.

PO6. The engineer, industry and society: Apply contextual knowledge to assess industrial, societal and safety related issues and understand consequent relevance to the professional engineering practice.

PO7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. **Communication**: Communicate effectively on complex engineering activities such as, being able to understand and write effective reports, make effective presentations, and give and receive clear instructions.

PO11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team in multidisciplinary environments.

PO12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

PSO 1. Analyse, design and develop electrical engineering systems considering green energy aspects in emerging applications like electric vehicles, renewable energy etc. PSO 2. Apply the knowledge of modern IT tools to Electrical Engineering applications.

Course Objectives

The objective of the course is to:

- 1. Make students familiar with concepts and analysis of power systems
- 2. Make students familiar with prototype model of power system
- 3. Make students able for understanding, analyzing performance of power system
- 4. Make students able to understand and correlate the theory with experiments based on power system.

Course Outcomes

Upon successful completion of the course, the student shall be able to

- 1. Apply and analyze fundamental principles of power system Engineering with laboratory experimental work and programming work
- 2. Understand and perform the experiment, Analyze the observed data & make valid conclusion
- 3. Write Journal with effective presentation of diagrams and characteristics
- 4. Use the modern software like MATLAB for plotting and analyzing power system

Course Outcom	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PO1 2	PSO 1	PSO 2
e 1	3	3											3	2
2	3	3											3	2
3	3	3											3	2
4	3	3											3	2

Mapping of CO with PO and PSO

Parameter=>	Attendance and Performance		Journal Writing		Viva-Voce		
COs	1,2,4		2,3		1,2		
Addressed							
Total Marks	10		10		5		
Marks	Present	2	Clarity of Aim	2	Understanding of	1	
Distribution					Aim		
(Sub-	Proper simulation	2	Clarity of Circuit	2	Understanding of	2	
Parameters)			dig.and		Theory Behind the		
			simulation		Experiment and		
			diagram		simulation		
	Understanding of	4	Clear	2	Understanding of	2	
	Experiment		Understanding of		practical		
	Performance		Calculations and		Applications		
			simulation				
			results				
	Correct	2	Validity of	2			
	Observations		Result				
			Conclusion	2			

Rubrics for laboratory work evaluation and evaluation Scheme

Laboratory experiment index

- 1. Study of transmission Line Model
- 2. To study methods for load flow analysis.
- 3. Study of PSAT software for MATLAB
- 4. To simulate transmission line model and perform load flow analysis using PSAT
- 5. To simulate six bus system and perform load flow analysis using PSAT
- 6. To study Ferranti effect on long transmission line using PSAT
- 7. To study dynamic response of change in frequency of isolated single area system
- 8. Three phase fault analysis using Power World Simulator

Laboratory experiment details

All the experiments are to be performed on Simulation Softwares like MATLAB, PSAT and Power World Simulator

Experiment 1

Study of Transmission Line Model

The transmission line model used in the project is High Voltage Transmission Line Analyser

(VPST-100HV1). This model comprises of five sections, which are: -

- a. Generating Station
- b. Transmission Line Model c. Receiving Station
- d. Compensator Section e. RLC Loading Section
- a. Generating Station

The Generating Station is shown with a generator model from which the line is fed, the sending end is provided with a step up transformer from which different ranges of voltage ranging from 110/220V can be obtained. Figure 1 shows the generating station and dimmerstat attached with the generating station.



Figure 1 A. Generating Station



Figure 1 B. Dimmerstat attached generating station

b Transmission Line Model

The transmission line is considered for length of 180 km. The line may be used as 180 km, 3ϕ line or 540 km, 1ϕ line. The line inductance is taken for every 30 km and capacitance for every 15 km. The actual value of line parameters of 220 KV transmission line are 0.03333 Ω /km,1.06mH/km and 7.33nF/km. Figure 2 shows the arrangement of transmission line model.



Figure 2 Transmission Line Model

c. Receiving Station

The receiving station is provided with a step down transformer from which different ranges of voltage ranging from 110/220V can be obtained. Figure 3 shows the Receiving Station.



Figure 3 Receiving Station

d. Compensator Section

It consists of shunt capacitors for voltage control and series reactor to reduce the fault current during fault conditions.

- Shunt capacitor: 3ϕ delta connected shunt capacitor of 1 KVAR 4 numbers are available as independent units.
- Shunt reactor: A 3 numbers of 0 to 1700mH variable inductance available for compensation under no load condition.
- Series reactor: Series reactor with inductance 0mH to 120mH available in all the three phases for series compensation.
- e. RLC Loading Section

The loading section is provided with resistive load, Inductive load. The loading section is also provided with an ammeter to measure the load current and a voltmeter to measure the load end voltage. Figure 4 shows the Compensator section and RLC loading section



Figure 4 Compensator and RLC Loading Section

Experimentation work

The experiments can be conducted by connecting loads at different locations. The currents in various sections of transmission line, voltages on each bus, total powers consumed by the load can be obtained.

- 1. Resistive Load at the end
- 2. Induction Motor Load at the end
- 3. Resistive and Induction Motor Load at the end
- 4. Simultaneous Loading at the end with intermediate induction motor load

Experiment 2 Study of Load Flow Methods

What is "Load Flow"?

- Load flow is the steady state solution of the power system network.
- The main information obtained from the load flow study comprises of

-The magnitudes and phase angles of bus voltages.

-Power flows in transmission lines.

Need of Load Flow?

- Operation and control.
- ➢ planning.
- ➤ stability analysis.
- ➤ fault analysis.
- Security analysis.
 - System monitoring
 - Contingency analysis
 - System state classification

Bus Admittance Matrix

Consider a simple power system network



Complex power generated at ith bus $S_{Gi} = P_{Gi} + jQ_{Gi}$ Complex power demand at ith bus $S_{Di} = P_{Di} + jQ_{Di}$ Complex power injected into ith bus $S_i = S_{Gi} - S_{Di}$ Current injected into ith bus $I_i = I_{Gi} - I_{Di}$ V_i - Bus voltage y_{i0} - self admittance of bus-i

$$I_{1} = y_{10}V_{1} + y_{12}[V_{1} - V_{2}] + y_{14}[V_{1} - V_{4}]$$

$$I_{2} = y_{21}[V_{2} - V_{1}] + y_{20}V_{2} + y_{23}[V_{2} - V_{3}] + y_{24}[V_{2} - V_{4}]$$

$$I_{3} = y_{32}[V_{3} - V_{2}] + y_{30}V_{3} + y_{34}[V_{3} - V_{4}]$$

$$I_{4} = y_{41}[V_{4} - V_{1}] + y_{42}[V_{4} - V_{2}] + y_{43}[V_{4} - V_{3}] + y_{40}V_{4}$$

$$I_{1}$$

$$I_{2}$$

$$I_{3}$$

$$I_{4}$$

$$V_{1}$$

$$V_{2}$$

$$V_{3}$$

$$V_{4}$$

$$V_{4$$

$$I_{1} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} & Y_{14} \\ Y_{21} & Y_{22} & Y_{23} & Y_{24} \\ Y_{31} & Y_{32} & Y_{33} & Y_{34} \\ Y_{41} & Y_{42} & Y_{43} & Y_{44} \end{bmatrix} \begin{bmatrix} V_{1} \\ V_{2} \\ V_{3} \\ V_{4} \end{bmatrix}$$

$$I_{bus} = Y_{bus}V_{bus}$$

$$I_{1} = Y_{11}V_{1} + Y_{12}V_{2} + Y_{13}V_{3} + Y_{14}V_{4}$$
So we can write , $I_{i} = \sum_{k=1}^{n} Y_{ik}V_{k}$, for i=1,2.....n



Bus Admittance Matrix by Inspection

Diagonal entries,

 $Y_{bus}(i, i)$ = Sum of the admittances of all components connected to node i.

➢ Off-diagonal entries,

 $Y_{bus}(i, j)$ = Negative of sum of the admittance of all components connected between node i and j.

Is this method always applicable?

Effect of Tap changing Transformers

Let us consider a Tap-changing transformer with turns ratio '1/a' whose admittance is 'y'.



Inputs and outputs of load flow

- Inputs: real & reactive powers injected into the bus and network parameters
- Outputs: magnitude and phase angles of bus voltages



Power/load flow equations

Complex power at ith bus is given by

$$S_{i} = P_{i} + jQ_{i} = V_{i}I_{i}^{*}$$

= $V_{i}\sum_{k=1}^{n}(Y_{ik}V_{k})^{*}$
for i= 1,2,.....n.

Note: here ' θ ' is considered as bus voltage phase angle let

$$V_{i} = |V_{i}| \angle \theta_{i}, V_{k} = |V_{k}| \angle \theta_{k} \& Y_{ik} = G_{ik} + jB_{ik}$$

$$P_{i} = \sum_{\substack{k=1\\n}}^{n} |V_{i}||V_{k}| (G_{ik} \cos \theta_{ik} + B_{ik} \sin \theta_{ik}) \longrightarrow (1)$$

$$Q_{i} = \sum_{\substack{k=1\\n}}^{n} |V_{i}||V_{k}| (G_{ik} \sin \theta_{ik} - B_{ik} \cos \theta_{ik}) \longrightarrow (2)$$

$$Q_i = \sum_{k=1}^{k} |V_i| |V_k| (G_{ik} \sin \theta_{ik} - B_{ik} \cos \theta_{ik}) \quad \longrightarrow \quad (2)$$

Are these equations linear?

- As these equations are non-linear we have to use iterative methods to solve them.
- For an n-bus system, there will be '2n' equations with '4n' unknowns (P_i,Q_i,|V_i|,θ_i at each bus).
- How to solve these equations?
- Is the solution unique?

Types of buses

- 1) Generator bus/voltage controlled bus
- 2) Load bus
- 3) Slack bus

among 4 variables (P, Q, $|V| \& \theta$) two will be specified and the remaining will be unspecified

Type of bus	Specified variables	Unspecified variables
Generator bus	P & V	Q & 0
Load bus	P & Q	V & θ
Slack bus	V & O	P & Q

Need of slack bus

- Consider we are having 'n' buses ranging from 1 to n.
- ➢ If suppose all the given buses are load/generator buses, 'P_i' will be specified in both the cases, so "P_L = ∑_{i=1}ⁿ P_i = ∑_{i=1}ⁿ P_{Gi} − ∑_{i=1}ⁿ P_{Di}" is known.
- The term P_L in the above equation is evidently the total I²R loss in the transmission lines and transformers of the network.
- But the individual currents in the various transmission lines of the network cannot be calculated until after the voltage magnitude and angle are known at every bus of the system.

- There fore, P_L is initially unknown and it is not possible to prespecify all the quantities in the summations of the above eqn.
- In the formulation of the power flow problem we choose one bus ,as slack bus, at which P_i is not scheduled.
- After the power flow problem has been solved, the difference(slack) between the total specified 'P' going into the system at all the other buses and the total output power plus I²R losses are assigned to the slack bus.
- For this reason a generator bus must be selected as the slack bus.
- The voltage angle of the slack bus serves as reference for the angles of all other bus voltages

Application of Gauss-Seidel method to Load Flow problem

As we know,

$$S_i^* = P_i - jQ_i = V_i^* I_i$$
$$I_i = \frac{P_i - jQ_i}{V_i^*} \longrightarrow (3)$$

Also we know current injected into bus i,

$$I_i = \sum_{k=1}^n Y_{ik} V_k \quad \longrightarrow \quad (4)$$

From eqns. (3) & (4)

$$\frac{P_{i} - jQ_{i}}{V_{i}^{*}} = \sum_{k=1}^{n} Y_{ik}V_{k}$$
$$\frac{P_{i} - jQ_{i}}{V_{i}^{*}} = Y_{ii}V_{i} + \sum_{\substack{k=1\\\neq i}}^{n} Y_{ik}V_{k}$$

for all i=1,2.....n.

eqn. (5) is non-linear because it contains 'v_i*' term in denominator of the RHS term. In order to linearize eqn.(5) take 'v_i*' from the previous iteration.

for pth iteration,

$$(V_i)^p = \frac{1}{Y_{ii}} \left[\frac{P_i - jQ_i}{(V_i^*)^{p-1}} - \sum_{k=1}^{i-1} Y_{ik} (V_k)^p - \sum_{k=i+1}^n Y_{ik} (V_k)^{p-1} \right]$$

Algorithm for Gauss-Seidel Load Flow with only PQ_buses:

<u>Step 1</u>: make initial guesses for bus voltages as $V_i^{(0)}$

for all i=2,3.....,n. and set iteration count p=1.

Step 2: calculate voltages at all buses(i=2,3.....,n) by using the relation

$$(V_i)^p = \frac{1}{Y_{ii}} \left[\frac{P_i - jQ_i}{(V_i^*)^{p-1}} - \sum_{k=1}^{i-1} Y_{ik} (V_k)^p - \sum_{k=i+1}^n Y_{ik} (V_k)^{p-1} \right]$$

<u>Step 3</u>: calculate the diff. b/w the voltages magnitudes of previous iteration and present iteration for all buses i=2,3,.....,n.

 $V_i(diff.) = |V_i^{(p)}| - |V_i^{(p-1)}|$

<u>Step 4</u>:

if

max(V₂(diff),V₃(diff).....,V_n(diff))≤ accuracy, stop iterations

else

set p=p+1 go to step_2.

Handling of PV_buses

We can't use the relation

$$(V_i)^p = \frac{1}{Y_{ii}} \left[\frac{P_i - jQ_i}{(V_i^*)^{p-1}} - \sum_{k=1}^{i-1} Y_{ik} (V_k)^p - \sum_{k=i+1}^n Y_{ik} (V_k)^{p-1} \right]$$

In order to find the angle 'θ', because we don't know 'Q' value, but we can use the values of voltages to estimate the 'Q'.So we first estimate the value of 'Q' for PV_busUsing the relation

$$Q_i = \sum_{k=1}^n |V_i| |V_k| (G_{ik} \sin \theta_{ik} - B_{ik} \cos \theta_{ik})$$

convergence properties

- whether the method will converge?
- how fast the method will converge?

For Newton-Raphson method, whether the method will converge or not depends on two things:

- 1) How close the guessed solution is to the correct solution.
- 2) The nature of the function close to the correct solution.

The NR-method converges "quadratically".

Quadratic convergence means that each iteration increases the accuracy of the solution by two decimal places.

N-R Application to Power Flow



Power Mismatch

• Defined by

$$\Delta \mathbf{P}(\mathbf{x}) \equiv \begin{bmatrix} P_2 - P_2(\mathbf{x}) \\ \vdots \\ P_n - P_n(\mathbf{x}) \end{bmatrix} \Delta \mathbf{Q}(\mathbf{x}) \equiv \begin{bmatrix} Q_2 - Q_2(\mathbf{x}) \\ \vdots \\ Q_n - Q_n(\mathbf{x}) \end{bmatrix}$$

We can express f(x) as,

$$\mathbf{f}(\mathbf{x}) \equiv - \begin{bmatrix} \Delta \mathbf{P}(\mathbf{x}) \\ \Delta \mathbf{Q}(\mathbf{x}) \end{bmatrix} = \mathbf{0}$$

 We use power mismatch to check convergence.

Jacobian matrix

 Jacobian matrix is the gradient of the power function with respect to voltage and angle.

$$\mathbf{J} = \begin{bmatrix} \mathbf{J}_{11} & \mathbf{J}_{12} \\ \mathbf{J}_{21} & \mathbf{J}_{22} \end{bmatrix}$$
$$\mathbf{J}_{11} = \frac{\partial \mathbf{P}(\mathbf{x})}{\partial \mathbf{\theta}} \quad \mathbf{J}_{12} = \frac{\partial \mathbf{P}(\mathbf{x})}{\partial |\mathbf{V}|} \quad \mathbf{J}_{21} = \frac{\partial \mathbf{Q}(\mathbf{x})}{\partial \mathbf{\theta}} \quad \mathbf{J}_{22} = \frac{\partial \mathbf{Q}(\mathbf{x})}{\partial |\mathbf{V}|}$$

Off-diagonal Elements of Jacobian Matrix



they look somewhat similar.

Diagonal Elements of Jacobian Matrix

• For indices p=q

$$J_{pp}^{11} = \frac{\partial P_p(X)}{\partial \theta_p} = \sum_{\substack{q=1\\ \neq p}}^n |V_p| |V_q| (B_{pq} \cos \theta_{pq} - G_{pq} \sin \theta_{pq})$$

$$J_{pp}^{21} = \frac{\partial Q_p(X)}{\partial \theta_p} = \sum_{\substack{q=1\\ \neq p}}^n |V_p| |V_q| (G_{pq} \cos \theta_{pq} + B_{pq} \sin \theta_{pq})$$

$$J_{pp}^{12} = \frac{\partial P_p(X)}{\partial |V_p|} = 2 |V_p| G_{pp} + \sum_{\substack{q=1\\ \neq p}}^n |V_q| (G_{pq} \cos \theta_{pq} + B_{pq} \sin \theta_{pq})$$

$$J_{pp}^{22} = \frac{\partial Q_p(X)}{\partial |V_p|} = -2 |V_p| B_{pp} + \sum_{\substack{q=1\\ \neq p}}^n |V_q| (G_{pq} \sin \theta_{pq} - B_{pq} \cos \theta_{pq})$$

Modified Diagonal Elements of Jacobian Matrix

For indices p = q,

$$J_{pp}^{11} = \frac{\partial P_p(\mathbf{x})}{\partial \theta_p} = -Q_p - B_{pp} |V_p|^2$$
$$J_{pp}^{21} = \frac{\partial Q_p(\mathbf{x})}{\partial \theta_p} = P_p - G_{pp} |V_p|^2$$
$$J_{pp}^{12} = \frac{\partial P_p(\mathbf{x})}{\partial |V_p|} = \frac{P_p}{|V_p|} + G_{pp} |V_p|$$
$$J_{pp}^{22} = \frac{\partial Q_p(\mathbf{x})}{\partial |V_p|} = \frac{Q_p}{|V_p|} - B_{pp} |V_p|$$



Note that $J_{12} \neq J_{21}$ however, they look somewhat similar.

Handling of PV_buses

- For PV-buses 'Q' is unspecified, so there will no equation corresponds to ΔQ, so the jacobian consists of only one row corresponds to ΔP.
- we first estimate the value of 'Q' for PV_bus
 Using the relation

$$Q_i = \sum_{k=1}^n |V_i| |V_k| (G_{ik} \sin \theta_{ik} - B_{ik} \cos \theta_{ik})$$

• We will proceed in the same as that of Gauss-seidel load flow.

Computational Challenges with N-R

• Large-Size of Jacobian matrix

-For n-bus network, Jacobian matrix size may reach 2(n-1) by 2(n-1) matrix.

-Sparse matrix.

• Need to re-evaluate and take inverse of the Jacobian matrix at every iteration.

Comparison of Load Flow Techniques

Gauss seidal method	Newton-Raphson method
1. Computer memory requirement is less.	1. Computer memory requirement is large, as the elements of jacobian matrix are to be computed in each iteration.
2. Time taken for each iteration is very less.	2. Time taken for each iteration is very high.
3. It takes more number of iterations.	3. It takes less number of iterations.
Experiment 3 Study of PSAT Software for MATLAB PSAT SOFTWARE

1.1 Introduction

PSAT is a Matlab toolbox for electric power system analysis and control. The command line version of PSAT is also GNU Octave compatible. PSAT includes power flow, continuation power flow, optimal power flow, small signal stability analysis and time domain simulation. All operations can be assessed by means of graphical user interfaces (GUIs) and a Simulink-based library provides an user friendly tool for network design.

PSAT core is the power flow routine, which also takes care of state variable initialization. Once the power flow has been solved, further static and/or dynamic analysis can be performed. These routines are:

- 1. Continuation power flow;
- 2. Optimal power flow;
- 3. Small signal stability analysis;
- 4. Time domain simulations;
- 5. Phasor measurement unit (PMU) placement.

1.2 PSAT Software Structure

In order to perform accurate power system analysis, PSAT supports a variety of static and dynamic component models, as follows:

- Power Flow Data: Bus bars, transmission lines and transformers, slack buses, PV generators, constant power loads, and shunt admittances.
- CPF and OPF Data: Power supply bids and limits, generator power reserves, generator ramping data, and power demand bids and limits.
- Switching Operations: Transmission line faults and transmission line breakers.
- Measurements: Bus frequency and phasor measurement units (PMU).
- Loads: Voltage dependent loads, frequency dependent loads, ZIP (impedance, constant current and constant power) loads, exponential recovery loads [Hill 1993, Karlsson and Hill 1994], thermostatically controlled loads [Hirsch 1994], Jimma's loads [Jimma et al. 1991], and mixed loads.
- Machines: Synchronous machines (dynamic order from 2 to 8) and induction motors (dynamic order from 1 to 5).

- Controls: Turbine Governors, Automatic Voltage Regulators, Power System Stabilizer, Over-excitation limiters, Secondary Voltage Regulation (Central Area Controllers and Cluster Controllers), and a Supplementary Stabilizing Control Loop for SVCs.
- Regulating Transformers: Load tap changer with voltage or reactive power regulators and phase shifting transformers.
- FACTS: Static Var Compensators, Thyristor Controlled Series Capacitors, Static Synchronous Source Series Compensators, Unified Power Flow Controllers, and High Voltage DC transmission systems.
- Wind Turbines: Wind models, Constant speed wind turbine with squirrel cage induction motor, variable speed wind turbine with doubly fed induction generator, and variable speed wind turbine with direct drive synchronous generator.
- Other Models: Synchronous machine dynamic shaft, sub-synchronous resonance model, Solid Oxide Fuel Cell, and sub-transmission area equivalents.

Besides mathematical routines and models, PSAT includes a variety of utilities, as follows:

1. One-line network diagram editor (Simulink library);

2. GUIs for settings system and routine parameters;

3. User defined model construction and installation;

4. GUI for plotting results;

5. Filters for converting data to and from other formats;

6. Command logs.

Finally, PSAT includes bridges to GAMS and UWPFLOW programs, which highly extend PSAT ability of performing optimization and continuation power flow analysis. Figure 1 shows the Structure of PSAT.



Figure 1 PSAT Structure

4.3 Graphical User Interface (GUI)

PSAT provides interfaces to GAMS and UWPFLOW, which highly extend PSAT ability to perform OPF and CPF analysis respectively. The General Algebraic Modeling System (GAMS) is a high-level modeling system for mathematical programming problems. It consists of a language compiler and a variety of integrated high-performance solvers. GAMS is specifically designed for large and complex scale problems, and allows creating and maintaining models for a wide variety of applications and disciplines [Brooke et al. 1998] and the GUI which interfaces PSAT to GAMS. UWPFLOW is an open source program for sophisticated continuation power flow analysis [Ca⁻nizares and Alvarado 2000]. It consists of a set of C functions and libraries designed for voltage stability analysis of power systems, including voltage dependent loads, HVDC, FACTS and secondary voltage control. Figure 2 shows PSAT GUI interface.

PSAT 2.1.10				_		×
ile Edit Run Tools Interfaces View Options Help						
🖻 🚯 😩 🚺 🖬 😣	🇊 🛇 🗅 🖑 🕂	<u>₩</u>	÷ 🖹 🔊	4	62	?
Data File						
			50	Freq. B	lase (Hz)	
Perturbation File			100	Power	Base (MVA)
			0	Starting	g Time (s)	
Command Line			20	Ending	Time (s)	
			1e-05	PF Tole	erance	
<empty></empty>		^	20	Max Pf	= Iter.	
			1e-05	Dyn. To	blerance	
		~	V 20 Max Dyn. Iter.			
		г				
PSAT	Power Flow		Time Domain		Settings	
	CPF		Load System		Plot	
Version 2.1.10 May 26, 2016	OPF		Save System Close			
PSAT version 2.1.10, Copyright (C)	2002-2016 Federico Milano					

Figure 2 Main graphical user interface of PSAT

1.4 Loading of Data

PSAT has its own Simulink Library; loading of the data in each block is explained in this section.

• Bus : - The network topology is defined by the "bus" components, whose data format is depicted in Figure 3.

Block Parameters: Bus1	×
Bus (mask)	
Bus block.	
Parameters	
Number of inputs:	
1	
Number of outputs:	
2	
Voltage Rating [kV]	
0.120	
Voltage initial guess [p.u. rad]	
[1.06 0.00]	
Area number	
1	
Region number	
1	
OK Cancel Help Appl	У

Figure 3 Bus parameter block

• Transmission Line: - Figure 4 depicts the block parameters used for defining the transmission line lumped model.

😼 Block Parameters: Line1		\times
Line (mask)		
This block defines a pi model for a tree	phase line.	
Parameters		
Power, Voltage and Frequency Ratings	[<mark>MVA, kV,</mark> Hz]]
[100 0.120 50]		
Length of line [km] (0 for p.u. parameter	ers)	
0		
Resistance [p.u. (Ohms/km)]		
0.0452		
Reactance [p.u. (H/km)]		
0.1852		
Susceptance [p.u. (F/km)]		
0.04080		
Imax, Pmax and Smax [p.u., p.u., p.u.]		
[0.0 0.0 0.0]		
OK Cancel	Help	Apply

Figure 4Transmission line block parameter

• Slack Bus: - Slack bus parameters are shown in figure 5 given below.

Block Parameters: Slack	×
SW (mask)	^
This block defines a V-theta bus:	
V = V_des theta = theta_des	
Parameters	
Power and Voltage Ratings [MVA, kV]	
[100 0.120]	
Voltage Magnitude [p.u.]	
1.06	
Reference Phase Angle [rad]	
0.00	
Qmax and Qmin [p.u. p.u.]	
[0 0]	
Vmax and Vmin [p.u. p.u.]	1.
[1.1 0.9]	
Active Power Guess [p.u.]	
0	
Loss Participation Factor	
1	
Reference bus	
Connected	~
OK Cancel Help Ap	ply

Figure 5 Slack bus block parameters

• PQ bus: - PQ bus or load bus is used to provide load in PSAT software. The block parameter of PQ bus is shown in figure 6.

Block Parameters: PQ ×
PQ (mask)
This block defines a constant power load:
P = Pcost.
Q = Qcost.
Parameters
Power and Voltage Ratings [MVA, kV]
[0.63e-3 0.415]
Active and Reactive Powers [p.u. p.u.]
[0.80 0.60]
Maximum and Minimum Allowable Voltage [p.u. p.u.]
[1.2 0.8]
✓ Allow conversion to impendance for min or max voltage
✓ Connected
OK Cancel Help Apply

Figure 6 PQ bus parameters block

• PV Bus: - PV bus or Generator bus used to provide generator in PSAT software. The block parameter of PV bus is shown in figure 7.

Block Parameters: PV	×
PV (mask)	
This block defines a PV bus for load flow studies:	
P = Pcost. V = Vdes.	
Parameters	
Power and Voltage Ratings [MVA, kV]	
[100 0.120]	
Active Power [p.u.]	
0.40	
Voltage Magnitude [p.u.]	
1.043	
Qmax and Qmin [p.u. p.u.]	
[0.5 -0.4]	
Vmax and Vmin [p.u. p.u.]	
[1.1 0.9]	
Loss Participation Factor	
1	
☑ Connected	
OK Cancel Help	Apply

Figure 7 PV bus parameters block

• Shunt Compensator block: - It is basically a PV bus block which has active power (P) equals to 0. Figure 18 shows the Shunt Compensator Parameter Block.

🔁 Block Parameters: SC	\times
PV (mask)	
This block defines a static synchronous compensator: P = 0 V = V dos	
Parameters	
Power and Voltage Ratings [MVA, kV]	
[100 0.120]	
Voltage Magnitude [p.u.]	
1.071	
Qmax and Qmin [p.u. p.u.]	
[0.24 -0.06]	
Vmax and Vmin [p.u. p.u.]	-2
[1.1 0.9]	
Loss Participation Coefficient	
1	
OK Cancel Help	Apply

Figure 8 Shunt Compensator Parameter Block

• Transformer Block: - Transformer parameter block shown in figure 9.

🔁 Block Parameters: Transf3	×
Line (mask)	
This block defines a transformer.	
Parameters	
Power, Voltage and Frequency Ratings [MVA, kV, Hz]	
[100 0.120 50]	
Primary and secondary voltage ratio [kV/kV]	
0.932	
Resistance [p.u.]	
0.00	
Reactance [p.u.]	
0.2560	
Imax, Pmax and Smax [p.u., p.u., p.u.]	
[0.0 0.0 0.0]	
Connected	
OK Cancel Help	Apply

Figure 9 Transformer Parameter Block

• Three Winding Transformer: - Transformer block which has single input and two outputs. Parameters block for three winding transformer is shown in figure 10

Block Parameters: Twt2			\times
Twt (mask)			^
This block defines a three tap ratio.	e-winding tran	sformer with co	nstant
Parameters			
Power and Frequency Rat	tings [MVA, H	z]	
[100 50]			
Voltage Ratings Vn1, Vn2	and Vn3 [kV,	kV, kV]	
[0.120 0.117 0.116]			
Resistances R12, R13 an	d R23 [p.u. p	.u. p.u.]	
[0 0 0]			
Reactances X12, X13 and	1 X23 [p.u. p.	u. p.u.]	
[0.1 0.2080 0.5560]			
Fixed tap ratio [p.u./p.u.]	I		
1.00			
Max Currents Imax1, Ima	x2 and Imax3	[p.u. p.u. p.u.]
[0.0 0.0 0.0]			
Max Powers Pmax1, Pma	x2 and Pmax3	[p.u. p.u. p.u.]	
[0.0 0.0 0.0]			
Max Powers Smax1, Sma	x2 and Smax3	[p.u. p.u. p.u.]	
[0.0 0.0 0.0]			
Connected			~
ОК	Cancel	Help	Apply

Figure 10 Three winding transformer parameter block

• Demand Parameter Block: - Block used to increase the load on the buses is known as the Demand Parameter Block. Figure 11 shows the Demand Block Parameter Block.

🛅 Block Parameters: Demand	\times
Demand (mask)	^
This block defines a constant power load for bifurcation and market studies.	
Parameters	
Power Rating [MVA]	
100]
Active Power [p.u.]	
0.80	
Reactive Power [p.u.]	
0.60	
Max and Min Power Demand [p.u. p.u.]	
[1.00 0.00]	
Cost = a + b*P + c*P^2 [\$/h, \$/MWh, \$/(MW)^2 h]	
[0.00 10.5 0.00]	
$Cost = a + b*Q + c*Q^2 [$/h, $/MVArh, $/(MVAr)^2 h]$	
[0.00 0.00 0.00]]
Allow Unit Commitment	
Tie Breaking Cost [\$/h]	
0	
Up and down congestion costs [\$/h \$/h]	
[0 0]	
OK Cancel Help App	ly

Figure 11 Demand Block Parameter Block

• Supply Parameter Block: - Block which defines a PV Bus for Bifurcation, is known Supply Block. Figure 12 shows Supply Block Parameter Block.

Block Parameters: Supply	\times
Supply (mask)	^
This block defines a PV bus for bifurcation and market studies:	
Parameters	
Power Rating [MVA]	
100	
Active Power [p.u.]	
0.80	
Max and Min Power Supply [p.u. p.u.]	
[1.00 0.00]	
Cost = a + b*P + c*P^2 [\$/h, \$/MWh, \$/(MW)^2 h]	
[0.00 8.80 0.00]	
Cost = a + b*Q + c*Q^2 [\$/h, \$/MVArh, \$/(MVAr)^2 h]	
[0.00 0.00 0.00]	
Allow Unit Commitment	
Tie Breaking Cost [\$/h]	
0	
Loss participation factor	
1	
Reactive power limits Qmax and Qmin [p.u. p.u.]	
[0 0]	_ `
OK Cancel Help Ap	ply

Figure 12 Supply Block Parameter Block

• SVC (Static VAR Compensator) Block: - The block assumes a time constant regulator, as depicted in Figure 13. In this model, a total reactance b_{SVC} is assumed and the following differential equation holds:

$$\hat{b}_{SVC} = \frac{K_r (V_{ref} + v_{POD} - V) - b_{SVC}}{T_r}$$

The model is completed by the algebraic equation expressing the reactive power injected at the SVC node:

$$Q = -b_{SVC} \times V^2$$

The regulator has an anti-windup limiter, thus the reactance b_{SVC} is locked if one of its limits is reached and the first derivative is set to zero.



Figure 13 SVC Block

• STATCOM Block: - The STATCOM current is always kept in quadrature in relation to the bus voltage so that only reactive power is exchanged between the ac system and the STATCOM. The dynamic model is shown in Figure 14 where it can be seen that the STATCOM assumes a time constant regulator like SVC. The differential equation and the reactive power injected at the STATCOM node are given by:

$$\widehat{\iota_{SH}} = \frac{K_r (V_{ref} + v_{POD} - V) - i_{SH}}{T_r}$$
$$Q = -i_{SH} \times V$$



Figure 14 STATCOM Circuit and Control Block Diagram.

The regulator has an non-windup limiter, thus the current i_{SH} is locked if one of its limits is reached and the first derivative is set to zero.

Experiment No.4

Aim: To simulate transmission line model and perform load flow analysis using PSAT

Appts: PSAT software, MATLAB software

PSAT Simulink blocks used: Bus, Slack bus, transmission line pi model load

Circuit or simulation diagram:



Slack bus data:

d	🔁 Block Parameters: Slack	Х
a	SW (mask)	^
l	This block defines a V-theta bus:	
ot	V = V_des theta = theta_des	
14	Parameters	
l	Power and Voltage Ratings [MVA, kV]	
l	[6.512e-3 0.415]	
	Voltage Magnitude [p.u.]	
l	1.00	
l	Reference Phase Angle [rad]	
l	0.00	
l	Qmax and Qmin [p.u. p.u.]	
l	[1 0]	
l	Vmax and Vmin [p.u. p.u.]	
l	[1.1 0.9]	
l	Active Power Guess [p.u.]	
l	0.80	
	Loss Participation Factor	~
	OK Cancel Help Apply	

Bus Data:

🚹 Block Parameters: Bus1	Х
Bus (mask)	
Bus block.	
Parameters	
Number of inputs:	
1	
Number of outputs:	
1	
Voltage Rating [kV]	
0.415	
Voltage initial guess [p.u. rad]	
[1.00 0.00]	
Area number	
1	
Region number	
1	
OK Cancel Help Apply	

Transmission line data:

	🔁 Block Parameters: Line1	\times
	Line (mask)	
1	This block defines a pi model for a tree phase line.	
-	Parameters	
1	Power, Voltage and Frequency Ratings [MVA, kV, Hz]	
1	[0.6e-3 0.220 50]	
	Length of line [km] (0 for p.u. parameters)	
	30	
	Resistance [p.u. (Ohms/km)]	
	0.03333	
1	Reactance [p.u. (H/km)]	
	1.06e-3	
	Susceptance [p.u. (F/km)]	
	7.33e-9	
	Imax, Pmax and Smax [p.u., p.u., p.u.]	
	[1 1 1]	
	Connected	
	OK Cancel Help Appl	У

PQ load Data:

🛅 Block Parameters: PQ 🛛 🗙								
PQ (mask)								
This block defines a constant power load:								
P = Pcost.								
Q = Q cost.								
Parameters								
Power and Voltage Ratings [MVA, kV]								
[0.63e-3 0.415]								
Active and Reactive Powers [p.u. p.u.]								
[1 0.6]								
Maximum and Minimum Allowable Voltage [p.u. p.u.]								
[1.2 0.8]								
Allow conversion to impendance for min or max voltage								
Connected								
OK Cancel Help Apply								

Procedure:

- 1) Open MATLAB
- 2) Browse for PSAT folder to give the path
- 3) Write PSAT in command prompt. This opens up PSAT GUI window.

POAL	2.1.10									_		
Edi	t Run	Tools	Interf	aces	View	Options	Help					
2	D 省	à 🖬		*	\odot	D 🖦	-÷ 🏊	्रे 🔮 🔜	2 🚽	1	69	?
	Data File											
								5	0	Freq.	base (Hz	.)
	Perturba	tion File						1	00	Powe	r Base (N	IVA)
								C)	Startin	ig Time (s	s)
	Comman	d Line						2	0	Ending	g Time (s))
								1	e-05	PF Tol	erance	
	<empty></empty>						^	2	0	Max P	F Iter.	
								1	e-05	Dyn. T	olerance	
							~	2	20	Max D	yn. Iter.	
				,								
PS.	АТ 🎽	the star	18-		Po	wer Flow		Time Domai	n		Settings	
		-7				CPF		Load System	n		Plot	
	sion 2.1.1	0				OPE		Save System	,		Close	

- 4) Open New model in MATLAB and using PSAT Simulink create/draw the model.
- 5) Save the model with name in some folder.

- 6) Double click on data file
- 7) Select filters, PSAT model
- 8) In current path browse for the PSAT Simulink model created
- 9) Load the model

e Edit	Run	Tools	Interfaces	View (Options	Help						
2	1 省	<u>à</u> 🗖	8		2 5		्रे 🔮 [~	39 🐗		69	1
	Data File											
	transmis	sion_line	_model_moto	r(mdl)]	50		Freq.	Base (Hz)
	Parturbat	ion File						10	0	Powe	r Base (N	IVA
	Ferturba	ion nic]	0		Startin	ng Time (s	s)
	Comman	lline						20		Ending	g Time (s))
		2]	1e-	-05	PF To	erance	
	<empty></empty>					^		20		Max P	F Iter.	
								1e-	-05	Dyn. T	Folerance	
						~		20		Max D	yn. Iter.	
										_		
PSA	лт 🎽	THE P	10	Pow	er Flow		Time Do	main			Settings	
		-7			CPF		Load Sys	stem			Plot	
Vers	ion 2.1.1)		(OPF		Save Sys	stem			Close	

- 10) Click power flow
- 11) Click static report and then report
- 12) Open text file for report (Example: file: 'C:\Users\Naik Sir\Desktop\original Trnsm line models\transmission_line_model_motor_01.txt')

Load flow report

POWER FLOW REPORT

PSAT 2.1.10 NETWORK STATISTICS

Buses:	7	
Lines:	6	
Generators:	1	
Loads:	1	
SOLUTION STAT	ISTICS	
Number of Iterations	:	1
Maximum P mismate	ch [p.u.]	0
Maximum Q mismat	ch [p.u.]	0
Power rate [MVA]	100)

POWER FLOW RESULTS

Bus	V	phase	P gen	Q gen	P load	Q load
	[p.u.]	[rad]	[p.u.]	[p.u.]	[p.u.]	[p.u.]

Bus1	1	0	1e-05	1e-05	0	0
Bus2	0.96265	-0.03503	0	0	0	0
Bus3	0.92587	-0.07276	0	0	0	0
Bus4	0.88987	-0.1135	0	0	0	0
Bus5	0.85486	-0.15756	0	0	0	0
Bus6	0.82106	-0.20524	0	0	0	0
Bus7	0.78871	-0.25686	0	0	1e-05	0

LINE FLOWS

From Bus	To Bus		Line [p.u.]	P Flov [p.u.]	w Q Flo [p.u	ow .]	P Los [p.u.]	s Q Loss
Bus1	Bus2		1	1e-05	1e-0)5	0	0
Bus2	Bus3		2	1e-05	1e-	05	0	0
Bus3	Bus4		3	1e-05	1e-	-05	0	0
Bus4	Bus5		4	1e-05	0		0	0
Bus5	Bus6		5	1e-05	0		0	0
Bus6	Bus7		6	1e-05	0		0	0
LINE FL	OWS							
From Bus	To Bus	Line	P Flo	OW	Q Flow	P Lo	oss	Q Loss
		[p.u.]	[p.u.]		[p.u.]	[p.u	.]	
Bus2	Bus1	1	-1e-05	5	-1e-05	0		0
Bus3	Bus2	2	-1e-05		-1e-05	0		0
Bus4	Bus3	3	-1e-05		0	0		0
Bus5	Bus4	4	-1e-05		0	0		0
Bus6	Bus5	5	-1e-05		0	0		0
Bus7	Bus6	6	-1e-05		0	0		0

GLOBAL SUMMARY REPORT

TOTAL GENERATION	
REAL POWER [p.u.]	1e-05
REACTIVE POWER [p.u.]	1e-05
TOTAL LOAD	
REAL POWER [p.u.]	1e-05
REACTIVE POWER [p.u.]	0
TOTAL LOSSES	
REAL POWER [p.u.]	0
REACTIVE POWER [p.u.]	0

Result and Conclusion:

Load flow using N-R method is performed on simulated transmission line model. Bus voltages and line flows are found.

Experiment No.5

Aim: To simulate six bus system and perform load flow analysis using PSAT

Appts: PSAT software, MATLAB software

PSAT Simulink blocks used: Bus, Slack bus, transmission line pi model load

Circuit or simulation diagram:



Line Data:

Block Parameters: Line8	\times							
Line (mask)								
This block defines a pi model for a tree phase line.								
Parameters								
Power, Voltage and Frequency Ratings [MVA, kV, Hz]								
[100 400 60]								
Length of line [km] (0 for p.u. parameters)								
0								
Resistance [p.u. (Ohms/km)]								
0.07								
Reactance [p.u. (H/km)]								
0.2								
Susceptance [p.u. (F/km)]								
0.05								
Imax, Pmax and Smax [p.u., p.u., p.u.]								
[0.9147 0.0 0.0]								
Connected								
OK Cancel Help Appl	у							

PQ Load Data:

Block Parameters: ESCO 3	×
PQ (mask)	
This block defines a constant power load:	
P = Pcost. Q = Qcost.	
Parameters	
Power and Voltage Ratings [MVA, kV]	
[100 400]	
Active and Reactive Powers [p.u. p.u.]	
[0.90 0.60]	
Maximum and Minimum Allowable Voltage [p.u. p.u.]	
[1.1 0.9]	
Allow conversion to impendance for min max voltage	
Connected	
OK Cancel Help Appl	y

PV block data:

	Block Parameters: GENCO 1	\times
la	PV (mask)	^
	This block defines a PV bus for load flow studies:	
	P = Pcost. V = Vdes.	
1	Parameters	
	Power and Voltage Ratings [MVA, kV]	
	[100 400]	
	Active Power [p.u.]	
	0.9	
	Voltage Magnitude [p.u.]	
	1.05	
	Qmax Qmin [p.u. p.u.]	
	[1.5 -1.5]	
	Vmax Vmin [p.u. p.u.]	
	[1.1 0.9]	
	Loss Participation Factor	
	1	
	☑ Connected	~
	OK Cancel Help Appl	у

Slack bus data:

Block Parameters: GENCO 2	×					
SW (mask)	^					
This block defines a V-theta bus:	F					
V = V_des theta = theta_des						
Parameters	_					
Power and Voltage Ratings [MVA, kV]						
[100 400]						
Voltage Magnitude [p.u.]						
1.05						
Reference Phase Angle [rad]						
0.00						
Qmax and Qmin [p.u. p.u.]						
[1.5 -1.5]						
Vmax and Vmin [p.u. p.u.]						
[1.1 0.9]						
Active Power Guess [p.u.]						
1.4						
Loss Participation Factor	~					
OK Cancel Help A	pply					

Power flow run:

			4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
承 PSAT 2.1.10			- 🗆 ×
File Edit Run Tools Interfaces	View Options Help		צ
🖆 🚯 😩 🗋 😫 🎁	⊘ 🗅 🤭 🖃 🗠	🔅 🔮 🔜 🤧 📣	
Data File			
self_d_006(mdl)		50	Freq. Base (Hz)
Perturbation File		100	Power Base (MVA)
		0	Starting Time (s)
Command Line		20	Ending Time (s)
		1e-05	PF Tolerance
<empty></empty>	^	20	Max PF Iter.
		1e-05	Dyn. Tolerance
	¥	20	Max Dyn. Iter.
1 0			
	Power Flow	Time Domain	Settings
0.5	CPF	Load System	Plot
	OPF	Save System	Close
5 10 15 20			
Power Flow completed in 0.594 s			

Static loa	ad flow repo	rt:					
POWER	FLOW REPO	ORT					
PSAT	2.1.10						
NETWO	RK STATIST	FICS					
Buses:		б					
Lines:		11					
Generato	rs:	3					
Loads:		3					
SOLUTI	ON STATIST	FICS					
Number	of Iterations:		4				
Maximur	n P mismatch	n [p.u.]	0				
Maximur	n Q mismatel	h [p.u.]	0				
Power ra	te [MVA]		100				
POWER	FLOW RESU	ULTS					
Bus	V	phase	Р	gen	Q gen	P load	Q load
	[p.u.]	[rad]	[]	p.u.]	[p.u.]	[p.u.]	[p.u.]
Bus1	1.05	0	1.4	4129	0.15614	0	0
Bus2	1.05	-0.077	17	0.9	0.85441	0	0
Bus3	1.05	-0.105	33	0.6	0.70478	0	0
Bus4	0.98791	-0.09	968	0	0	0.9	0.6
Bus5	0.96902	-0.13	298	0	0	1	0.7
Bus6	0.99148	-0.14	383	0	0	0.9	0.6
LINE FL	OWS						
From Bu	s To Bus	Line	P	Flow	Q Flow	P Loss	Q Loss
				[p.u.]	[p.u.]	[p.u.]	[p.u.]
Bus2	Bus3	1	0.1	1973	-0.05527	0.00067	-0.06279
Bus3	Bus6	2	0.5	50489	0.51018	0.00955	0.02691
Bus4	Bus5	3	0.0	8293	-0.03252	0.00142	-0.07376
Bus3	Bus5	4	0.2	1417	0.20211	0.01073	-0.02778
Bus5	Bus6	5	0.00)957	-0.10371	0.00062	-0.05581

Bus2	Bus4	6	0.44858	0.4	41924	0.0	01752	0.	01426
Bus1	Bus2	7	0.34655	-0.	17892	0.	01313	-0.	.01785
Bus1	Bus4	8	0.56853	0.	18753	0.0	01665	0.	02503
Bus1	Bus5	9	0.49783	0.	14754	0.0	02035	0.	01507
Bus2	Bus6	10	0.40826	0.	14834	0.	.01255	-0	.01629
Bus2	Bus5	11	0.25686	0.	18103	0.	.00973	-0	.01165
LINE FI	LOWS								
From Bu	ıs To B	us Line	e P Flo	w	Q Flo	W	P Los	s	Q Loss
			[p.	u.]	[p.u	.]	[p.	u.]	[p.u.]
Bus3	Bus2	1	-0.119	06	-0.007	52	0.000	67	-0.06279
Bus6	Bus3	2	-0.495	33	-0.4832	27	0.009	55	0.02691
Bus5	Bus4	3	-0.081	51	-0.0412	24	0.001	42	-0.07376
Bus5	Bus3	4	-0.203	44	-0.229	89	0.010	73	-0.02778
Bus6	Bus5	5	-0.008	95	0.0479)	0.0006	52	-0.05581
Bus4	Bus2	6	-0.431	06	-0.404	98	0.017	52	0.01426
Bus2	Bus1	7	-0.333	43	0.1610)7	0.013	13	-0.01785
Bus4	Bus1	8	-0.5518	38	-0.1624	.9	0.0166	65	0.02503
Bus5	Bus1	9	-0.4774	18	-0.1324	7	0.0203	35	0.01507
Bus6	Bus2	10	-0.3957	71	-0.1646	3	0.0125	55	-0.01629
Bus5	Bus2	11	-0.247	713	-0.192	.69	0.009	973	-0.01165
GLOBA	L SUMM	IARY RE	PORT						
TOTAL	GENER	ATION							
REAL P	OWER [p.u.]	2.912	9					
REACTIVE POWER [p.u.]		1.71	53						
TOTAL	LOAD								
REAL P	OWER [p.u.]	2.8						
REACT	IVE POV	VER [p.u.]	1.9						
TOTAL LOSSES									
REAL P	0.112	292							
REACT	IVE POW	VER [p.u.]	-0.1	846	6				

Result and conclusion:

Power flow is run by N-R method using PSAT simulated model of a six bus system. The bus voltages and line flows are found.

Expt.6

Aim: To study Ferranti effect on long transmission line using PSAT software

Appts: MATLAB software, PSAT software

PSAT Simulink blocks used: Bus, Slack bus, transmission line pi model load

Circuit or simulation diagram:



Slack bus

Block Parameters: Slack1	×					
SW (mask)	^					
This block defines a V-theta bus:						
V = V_des theta = theta_des						
Parameters						
Power and Voltage Ratings [MVA, kV]						
[100 16.5]						
Voltage Magnitude [p.u.]						
1.04	-					
Reference Phase Angle [rad]						
0.00						
Qmax and Qmin [p.u. p.u.]						
[99 -99]						
Vmax and Vmin [p.u. p.u.]						
[1.1 0.9]						
Active Power Guess [p.u.]						
0.80						
Loss Participation Factor						
OK Cancel Help Appl	у					

Bus 1

Block Parameters: Bus 1 ×
Bus (mask)
Bus block.
Parameters
Number of inputs:
1
Number of outputs:
1
Voltage Rating [kV]
16.5
Voltage initial guess [p.u. rad]
[1.00 0.00]
Area number
1
Region number
1
OK Cancel Help Apply

Transformer 1

🚹 Block Parameters:	Trasf1			×
Line (mask)				
This block defines a	transform	er.		
Parameters				
Power, Voltage and	Frequency	Ratings [MV/	A, kV, Hz]	
[100 16.5 60]				
Primary and second	lary voltage	e ratio [kV/kV]	
16.5/230				
Resistance [p.u.]				
0.0				
Reactance [p.u.]				
0.0576				
	aav [n.u. n			
Imax, Pmax and Sn	Iax p.u., p	.u., p.u.		
Imax, Pmax and Sn	lax [p.u., p	.u., p.u.j		



×
ly

Transmission Line

🔁 Block Parameters: Line1	×
Line (mask)	
This block defines a pi model for a tree phase line.	
Parameters	
Power, Voltage and Frequency Ratings [MVA, kV, Hz]	
[100 230 60]	
Length of line [km] (0 for p.u. parameters)	
0	
Resistance [p.u. (Ohms/km)]	
0.01	
Reactance [p.u. (H/km)]	
0.085	
Susceptance [p.u. (F/km)]	
0.088*2	
Imax, Pmax and Smax [p.u., p.u., p.u.]	
[0.0 0.0 0.0]	
OK Cancel Help App	ly

Bus 3

Block Parameters: Bus 3	×
Bus (mask)	
Bus block.	t
Parameters	
Number of inputs:	
1	
Number of outputs:	
1	
Voltage Rating [kV]	
230	
Voltage initial guess [p.u. rad]	
[1.00 0.00]	
Area number	
2	
Region number	
1	
OK Cancel Help Apply	1

Transformer 2

🔁 Block Parameters: Trasf2	\times						
Line (mask)		ł					
This block defines a transformer.							
Parameters							
Power, Voltage and Frequency Ratings [MVA, kV, Hz]							
[100 16.5 60]							
Primary and secondary voltage ratio [kV/kV]							
230/16.5							
Resistance [p.u.]							
0.0							
Reactance [p.u.]							
0.0576							
Imax, Pmax and Smax [p.u., p.u., p.u.]							
[0.0 0.0 0.0]							
Connected							
		1					
OK Cancel Help App	y						

Bus 4

Block Parameters: Bus 4	\times
Bus (mask)	
Bus block.	
Parameters	
Number of inputs:	
Number of outputs:	
1	
Voltage Rating [kV]	
16.5	
Voltage initial guess [p.u. rad]	
[1.00 0.00]	
Area number	
3	
Region number	
1	
OK Cancel Help Apply	/

Constant PQ Load

Block Parameters: PQ1	\times
PQ (mask)	
This block defines a constant power load:	
P = Pcost. O = Ocost.	
Parameters	_
Power and Voltage Ratings [MVA, kV]	
[100 16.5]	
Active and Reactive Powers [p.u. p.u.]	
[0.00012 0.0003]	
Maximum and Minimum Allowable Voltage [p.u. p.u.]	
[1.2 0.8]	
Allow conversion to impendance for min max voltage	
Connected	
OK Cancel Help Appl	y

Procedure

- 1. Open MATLAB
- 2. Open PSAT
- 3. Create model using PSAT Simulink library
- 4. Set the block parameters.
- 5. Set load nearly zero
- 6. Perform Load flow
- 7. Take Report

Report

Buses:	4
Lines:	1
Transformers:	2
Generators:	1
Loads:	1

SOLUTION STATISTICS

Number of Iterations:	3
Maximum P mismatch [p.u.]	0
Maximum Q mismatch [p.u.]	0
Power rate [MVA]	100

POWER FLOW RESULTS

Bus	V	phase	P gen	Q gen	P load	Q load	
	[p.u.]	[rad]	[p.u.]	[p.u.]	[p.u.]	[p.u.]	
Bus 1	1.04	0	0.00021	-0.19274	0	0	
Bus 2	1.0507	-1e-05	0	0	0	0	
Bus 3	1.0586	-0.000	9 0	0	0	0	
Bus 4	1.0586	-0.000	9 0	0	0.0001	2 0.000	3

LINE FLOWS

From Bus	s To Bus	Line	P Flow	Q Flow	P Loss	Q Loss
		[p.u.]	[p.u.]	[p.u.] [p.	.u.]	
Bus 3	Bus 2	1	-0.00012	-0.0003	9e-05	-0.19502
Bus 1	Bus 2	2	0.00021	-0.19274	0	0.00198
Bus 3	Bus 4	3	0.00012	0.0003	0	0
LINE FL	OWS					

From Bus	To Bus	Line	P Flow	Q Flow	P Loss	Q Loss
						· ·

[p.u.] [p.u.] [p.u.] [p.u.]

Bus 2	Bus 3	1	0.00021	-0.19472	9e-05	-0.19502
Bus 2	Bus 1	2	-0.00021	0.19472	0	0.00198
Bus 4	Bus 3	3	-0.00012	-0.0003	0	0

GLOBAL SUMMARY REPORT

TOTAL GENERATION

REAL POWER [p.u.]	0.00021
REACTIVE POWER [p.u.]	-0.19274

TOTAL LOAD

REAL POWER [p.u.]	0.00012
REACTIVE POWER [p.u.]	0.0003

TOTAL LOSSES

REAL POWER [p.u.]	9e-05
REACTIVE POWER [p.u.]	-0.19304

Conclusion:

It is found that receiving end voltage is greater than sending end voltage. Ferranti effect is verified.

Expt.7

Aim: To study Dynamic response of change in frequency of isolated single area system.

Appts: MATLAB software

MATLAB Simulink blocks used: Transfer Function, summing/adder, scope

Data of single area system:

A 250 Mw Synchronous generator has following data.

R=Speed regulation of governor=3

Ksg=Gain of speed governor=1

Tsg=Time constant of speed governor=0.4 Sec

 Δ Pc=Speed governor setting (Commanded change in frequency).

Kt=Gain of turbine=1

Tt=Turbine time constant=0.5 Sec

Tps=Power system time constant=20 Sec

Kps=Power system gain=100

 ΔP_D =Step load change =0.01 pu

Circuit Diagram/Block Diagram:

Speed Governing system of isolated single area system



MATLAB Simulation Diagram:



Sum:

-	
	🔁 Function Block Parameters: Sum 🛛 🗙
1	Sum
	Add or subtract inputs. Specify one of the following: a) string containing + or - for each input port, for spacer between ports (e.g. ++ - ++) b) scalar, >= 1, specifies the number of input ports to be summed. When there is only one input port, add or subtract elements over all dimensions or one specified dimension
	Main Signal Attributes
	Icon shape: rectangular
	List of signs:
	-
	Sum over: All dimensions
	OK Cancel Help Apply

Governor Transfer Function:

🔁 Function Block Parameters: Governor	×
Transfer Function with Initial States (mask) (link)	
Vector expressions for numerator, and denominator. Coefficients a in descending powers of s.	re
Parameters	
Numerator:	
Denominator:	
[0.4 1]	
Initial conditions:	
0	
OK Cancel Help App	oly

Turbine Transfer Function:

Function Block Parameters: Turbine > Transfer Function with Initial States (mask) (link) > Vector expressions for numerator, and denominator. Coefficients are in descending powers of s. >
Transfer Function with Initial States (mask) (link) Vector expressions for numerator, and denominator. Coefficients are in descending powers of s.
Vector expressions for numerator, and denominator. Coefficients are in descending powers of s.
Parameters
Numerator:
[1]
Denominator:
[0.5 1]
Initial conditions:
0
OK Cancel Help Apply

Power System transfer Function:

🔁 Function Block Parameters: Power System	\times
Transfer Function with Initial States (mask) (link)	_
Vector expressions for numerator, and denominator. Coefficients are in descending powers of s.	•
Parameters	_
Numerator:	
[100]	
Denominator:	
[20 1]	
Initial conditions:	
0	
OK Cancel Help Apply	

Sum 1:

🚹 Fund	ction Block Parameters: Sum1	×
-Sum-		
Add or a) strin (e.g. +- b) scala When t dimens	subtract inputs. Specify one of the following: g containing + or - for each input port, for spacer between ports + - ++) ar, >= 1, specifies the number of input ports to be summed. here is only one input port, add or subtract elements over all ions or one specified dimension	3
Main	Signal Attributes	
Icon sha	ape: rectangular	•
List of s	igns:	
-+		
0	OK Cancel Help Apply	

Step:

Source Block Parameters: Step1	×
Step	
Output a step.	
Parameters	
Step time:	
0	
Initial value:	
0	
Final value:	
0.01	
Sample time:	
0	
☑ Interpret vector parameters as 1-D	
☑ Enable zero-crossing detection	
OK Cancel Help	Apply

Speed Regulator Transfer Function:

🔁 Function Block Parameters: Speed Regulation 1/R 🛛 🛛 🗙
Transfer Function with Initial States (mask) (link)
Vector expressions for numerator, and denominator. Coefficients are in descending powers of s.
Parameters
Numerator:
[0.333]
Denominator:
[1]
Initial conditions:
0
OK Cancel Help Apply

Procedure;

- 1) Open MATLAB
- 2) Create Model using MATLAB Simulink library
- 3) Set all block parameters.
- 4) Perform simulation
- 5) Click on scope block
- 6) Convert the graph on scope to MATLAB figure
- 7) Name the axes of graph



Conclusion:

It is found that with free governor action frequency drops by 0.029 Hz in steady state for a step change of 0.01 Pu in load.

Expt.8

Aim: Three phase fault analysis using Power World Simulator

Appts: Power World Simulator software

Power System:



All impedances are expressed in Pu on common 100 MVA base.

Determine fault current and bus voltages for three phase fault on bus 3 if

- 1. Fault impedance is zero
- 2. Fault impedance is $Z_f = 0.16$ pu

Procedure:

- 1. Open PW simulator
- 2. File>new case. For better visibility go to options>Draw Grid>Grid horizontal =4. Grid Lines.
- 3. In Edit mode,Network>Bus. Name it Bus 1. Change display size to 15. Select it as system slack bus
- 4. Similarly draw other two buses
- 5. Network>transmission line. Draw line between Bus 1 and Bus 2. Insert line reactance. Go to Display and increase line width to 3
- 6. Similarly draw other two lines
- 7. Network>Generator. Click on the Bus1.Select fault parameters and set generator and transformer reactances. You can set display size and thickness also. Go to Power and voltage control tab and set Mw set point to any arbitrary value or zero.
- 8. Similarly Connect other generator to bus 2
- 9. Run Mode>Tools>Play (Green Button)>Fault Analysis. A new window opens.
- 10. Click on Bus 3. Balanced three phase faults. Set fault impedance (Z_f if any)
- 11. Click on Calculate
- 12. Results will be displayed

Simulation diagram:



Bus 1:

	let e u				
Bus Options		×			
Bus Number 1	Find By Number	Find			
Bus Name Bus 1	Find By Name				
Nominal Voltage 138.0	Nominal Voltage 138.0000 kV				
Labels no labels					
1	lumber Name				
Area Change	1 🔺 1				
Balancing Authority Change	1 1				
Zone Change	1 1				
Owner Change	1 1				
Substation Change					
Bus Information Displa	Attached Devices Geography Custom				
Bus Voltage					
Voltage (p.u.) 1.0000					
Angle (degrees) 0.000 Bus voltage Regulator Devices					
System Slack Bus					
ОК	Save Save to Aux	Cancel			
Bus 2:

Bus Optio	x x
Bus Number	r 🔁 Find By Number Find
Bus Name	Bus 2 Find By Name
Nominal Vol	tage 138.0000 kV
Labels .	no labels
	Number Name
Area	Change 1 1
Balancing Authority	Change 1 1
Zone	Change 1 1
Owner	Change 1 1
Substation	Change
Bus Informa	ation Display Attached Devices Geography Custom
Bus Voltag	e
Voltage (p	.u.) 1.0000
Angle (deg	prees) 0.000
System	Slack Bus
(DK Save Save to Aux Cancel

Gen. 1:

Bus Name Bus 1 Find By Name O Open Generator MVA Base ID I Find I I O (Joen) Generator MVA Base Internal Sequence Impedances R: X: Outpedance I Outpedance R: X: 0.00000 I Outpedance I Outpedance R: X: 0.00000 I Outpedance R: X: 0.00000 I Outpedance R: X: I Outpedance Neutral Grounded Internal Sequence Impedances R: 0.00000 I Outpedance R: 0.00000 0.10000 Neutral-to-Ground Impedance R: 0.00000 X: 0.00000 0.00001 X: 0.00000 X: 0.00000	us Number	1			Find B	By Nur	nber	Status				
ID 1 Find [@ Closed 100.00 rea Name 1 Fuel Type UN (Unknown) [PW=0] [EPC=0] ✓ Labels no labels Unit Type ✓ splay Information Power and Voltage Control Costs Fault Parameters Owners, Area, etc Custom Stability Generator Step Transformer R: 0.00000 X: 0.10000 Regative 0.00000 0.10000 Zero 0.00000 0.00001 Neutral-to-Ground Impedance R: 0.00000 X: 0.0000 X: 0.00000 X: 0.0000 X: 0.0000 X: 0.0000 X: 0.0000 X: 0.0000 X: 0.0000 X: 0.0000 X: 0.0000 X: 0.000	Bus Name	Bus1			Find	Find By Name			Open	Gene	rator MVA	Base
rea Name 1 Fuel Type UN (Unknown) [PW=0] [EPC=0] ✓ Labels no labels Unit Type ✓ Isplay Information Power and Voltage Control Costs Fault Parameters Owners, Area, etc Custom Stability Senerator Impedances © Neutral Grounded R: 0.00000 X: 0.00000 Internal Sequence Impedances R: X: 0.00000 Tap: 1.0000 Negative 0.00000 0.10000 R: 0.00000 X: 0.00000 Zero 0.00000 0.00001 X: 0.00000 X: 0.00000	ID	1			F	ind		•	Ciused	100	0.00	
Labels no labels Unit Type isplay Information Power and Voltage Control Costs Fault Parameters Owners, Area, etc Custom Stability Senerator Impedances	Area Name	1				Fuel	Туре	UN ((Unknown) [PW=0] [[EPC=0]	\sim
splay Information Power and Voltage Control Costs Fault Parameters Owners, Area, etc Custom Stability Senerator Impedances Internal Sequence Impedances R: 0.00000 X: 0.10000 Internal Sequence Impedances R: X: 0.00000 Tap: 1.00000 Neutral Grounded R: X: 0.00000 Tap: 1.00000 Negative 0.00000 0.10000 R: 0.00000 X: 0.00000 Zero 0.00000 0.00001 X: 0.00000 X: 0.00000	Labels	no lab	els			Unit	Туре					\sim
Senerator Impedances Neutral Grounded Internal Sequence Impedances R: X: Positive 0.00000 0.10000 Zero 0.00000 0.00001 Generator Step Transformer R: 0.00000 Tap: 1.00000 Neutral-to-Ground Impedance R: 0.00000 X: 0.00000 X: 0.00000 X: 0.00000 X: 0.00000 X: 0.00000	isplay Inform	mation	Power a	and Voltage Control	Costs	Faul	t Parame	eters	Owners, Ar	ea, etc	Custom	Stability
R: 0.0000 Internal Sequence Impedances R: 0.10000 R: X: Positive 0.00000 0.10000 Regative 0.00000 0.10000 Zero 0.00000 0.00001	Generator In	npedano	es		Genera	tor St	ep Trans	forme	r			
Internal Sequence Impedances R: X: 0.10000 Restrict 0.00000 0.10000 Tap: 1.00000 Negative 0.00000 0.10000 R: 0.00000 Zero 0.00000 0.00001 X: 0.00000	✓ Neut	ral Grou	nded		R:		0.000	00				
Internal Sequence Impedances R: X: Positive 0.00000 0.10000 Negative 0.00000 0.10000 Zero 0.00000 0.00001 X: 0.00000 X: 0.00000					X:		0.1000	00	Ī			
R: X: Positive 0.00000 0.00000 0.10000 R: 0.00000 R: 0.00000 X: 0.00000 X: 0.00000	Internal Sec	quence	Impedan	ces	Тар	:	1.0000	00				
Negative 0.00000 0.10000 R: 0.00000 Zero 0.00000 0.00001 X: 0.00000	Positive	R	.:	X:								
Negative 0.0000 0.1000 R: 0.00000 Zero 0.00000 0.00001 X: 0.00000	Negetive	0.000	200	0.10000	Neutral	-to-Gr	ound Im	pedar	nce			
2ero 0.0000 0.0001 X: 0.0000	Negauve	0.000	00	0.10000	R	:	0.000	00				
	Zero	0.000	00	0.00001	X :		0.000	00				

Gen. 1 Options:

Generator (Optior	ıs								\times
Bus Number	1			Find B	Find By Number Status					
Bus Name	Bus1			Find	By Name	Open		Generator MVA Base		
ID	1			F	Find			100	.00	
Area Name	1				Fuel Type	UN (Un	known) [P\	N=0] [EPC=0] ~	
Labels	no lab	els			Unit Type				\sim	
Display Inform	nation	Power and Ve	oltage Control	Costs	Fault Parame	ters O	wners, Area	a, etc	Custom Stabili	ty
Display Si Scale W Display Widt Pixel Thicknes M Anchore	ize	7.0 💌	Orientation Right Up Left Down	v Genera	Rotor Sh Fill ator	hape Da	og Bone Symbol wit or 2	h Color	~ 2	
OK		Save Save	e to Aux				Cancel		Help	

Gen. 2:

Generator	Options							×
Bus Number	2		Find By Number Status			tus		
Bus Name	Bus 2		Find	By Name		Open	Gene	rator MVA Base
ID	1		F	ind		Closed	100	0.00
Area Name	1			Fuel Type	UN ((Unknown) [P	W=0]	[EPC=0] ~
Labels	no labels			Unit Type				\sim
Display Inform	mation Power	and Voltage Control	Costs	Fault Parame	eters	Owners, Are	a, etc	Custom Stability
Generator In	npedances		Genera	tor Step Trans	forme	r		
	ral Croundad		R:	0.000	00			
	al Groundeu		X:	0.200	10	-		
-Internal Ser	quence Impeda	nces	Tap	1.000	20	-		
	R :	X :	, ap	1.0000	0			
Positive	0.00000	0.20000						
Negative	0.00000	0.20000	Neutral	-to-Ground Im	pedan	lice		
Zero	0.00000	0.00001	R.	. 0.0000		-		
			X :	0.0000	00			
ОК	Save	Save to Aux				Cancel		Help

Gen. 2 Options

]	Generator (Options								×
	Bus Number	2		Find B	y Number	Status				
э	Bus Name	Bus 2		Find	By Name	Ope	en	Gene	rator MVA E	Base
	ID	1		F	ind		sed	100	0.00	
_	Area Name	1			Fuel Type	UN (Un	known) [P\	N=0] [[EPC=0] ~	*
	Labels	no labels			Unit Type				~	1
	Display Inform	mation Power and V	oltage Control	Costs	Fault Parame	ters Ov	wners, Area	a, etc	Custom	Stability
	Display Si Scale W Display Widt Pixel Thickne	ize 7.0 + idth with Size h 4.67 + ss 5 + d	Orientation Right Up Left Down Link To New	Genera	Rotor Sh	Till Rotor with Colo	ng Bone Symbol wit r 2	h Colo	r 2	
1	ОК	Save Sav	e to Aux				Cancel		Help	

Line Parameters:

ine	From	Bus	To E	To Bus Circuit			nd By Numbers			
Number	3		2			F	ind By Names			
Name	Bus 3		Bus 2	2			ind			
Area Name	1 (1)		1 (1)				rom End Meter	-d		
Nominal kV	138.0		138.0)		Default Ov	ner (Same as F	From Bus)	
Labels	no label	s]				
Display Parar	meters F	ault Info	Owner, Area, Zo	one, Sub	Custom 9	Stability				
Status		Per Unit	Impedance Param	eters		MVA Limit	s			
Open		Series R	esistance (R)	0.00000	0	Limit A	1000.000	^		
Closed		Series R	eactance (X)	0.40000	0	Limit B	0.000			
Branch Device	Туре	Shunt C	narging (B)	0.00000	0	Limit C	0.000			
Line	\sim	Shunt Co	onductance (G)	0.00000	0	Limit D	0.000			
Allow Conso	olidation	Hasl	ine Shunts	Line S	hunts	Limit E	0.000			
longth 0	00					Limit F	0.000			
	.00 🖵					Limit G	0.000			
Calculate Impedance	e s>					Limit H	0.000			
						Limit I	0.000			
Open	s					Limit J	0.000			
Closed						Limit K	0.000	~		
Convert l	Line to Tra	nsformer								
D-FACTS	Devices or	n the Line	Has D-I	FACTS						

Results:

💽 Fault Analysis	Run Faults Abort						- 0	2
 Fault Definitions Single Fault Bus Records Lines Generators Loads Switched Shunt Buses Y-Bus Matrices Options Sequence Data Branches Buses Generators Mutual Impedances Switched Shunts 	Single Fault Calculate Clear Choose the Faulted Bus Sort by ○ Name	Clear/Close	Fault Location Bus Fault In-Line Fault Location % 0 Fault Impedance R: 0.00000 X: 0.16000	Fault Type Single Line-to Line-to-Line Fault Current Scale Current By If Magnitude: If Scaled Mag: If Angle:	p-Ground /: 1.00000 2.000 p. 2.000 p. 2.000 p. -90.00 de	 3 Phase Bala Double Line- Double Line- Subtransient I p.u. A 2.000 B 2.000 C 2.000 	nced to-Ground Phase Current deg. -90.00 150.00	
	Bus Records Lines Generators Loads S : □ □ □ □ + + + + + + + + + + + + + + +	Witched Shunt Buses 1 cords ¥ Geo ¥ Set ¥ hase Volt A Phase V 0.76000 C 0.68000 C 0.32000 C	(-Bus Matrices Columns ▼		 ○ Amps ○ Amps ○ f(x) ▼ □ □ □ hase Ang B P -120.00 -120.00 -120.00 	Options • hase Ang C 120.00 120.00 120.00		

Conclusion: For a Three phase fault on bus 3 the fault current for fault impedance of 0.16 pu is found to be 2.0 Pu.