LOAD FLOW AND STABILITY ANALYSIS OF MULTI-MACHINE POWER SYSTEMS IN ETAP

A Project report submitted in partial fulfilment

of the requirements for the degree of B. Tech in Electrical Engineering

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<u>To whom it may concern</u>

This is to certify that the project work entitled **LOAD FLOW AND STABILITY ANALYSIS OF MULTI-MACHINE POWER SYSTEMS IN ETAP** is the bona fide work carried out by **Aman Jaiswal** a student of B.Tech in the Dept. of Electrical Engineering, RCC Institute of Information Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015, affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), West Bengal, India, during the academic year 2018-19, in partial fulfilment of the requirements for the degree of Bachelor of Technology in Electrical Engineering and that this project has not submitted previously for the award of any other degree, diploma and fellowship.

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Signature of the Guide

Name:

Designation

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Signature of the HOD

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Designation

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Signature of the External Examiner

Name:

Designation:

ACKNOWLEDGEMENT

It is my great fortune that I have got opportunity to carry out this project work under the supervision of **Dr. Debasish Mondal** in the Department of Electrical Engineering, RCC Institute of Information Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015, affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), West Bengal, India. I express my sincere thanks and deepest sense of gratitude to my guide for his constant support, unparalleled guidance and limitless encouragement.

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Name and Signature of the Student

Place:

Date:

Abstract

Electric power system stability analysis has been recognized as an important and challenging problem for secure system operation of power systems when small or large disturbances occur in an interconnected power system. This project proposes load flow and transient stability analysis of multi-machine power systems in ETAP. The effect of application Power System Stabilizer (PSS) is also shown in this work.

The single diagram of multi-machine systems 6-bus and 9-bus systems has been configured in ETAP. For each multi-machine power system load flow and power flow analysis has been studied in ETAP environment. Results of load flow data are presented for each case. For transient stability analysis, the systems are simulated with three phase to earth fault and single phase fault in ETAP. The combination of AVR, Governor and PSS maintains synchronism during all kind of faults. The variations of rotor angle, bus voltage and machine speed are investigated in each case study. The result of simulations is shown through graphical analysis. In has been further observed that the application of PSS improves substantially the transient stability of the power systems.

CHAPTER 1: Introduction

1.1 LITERATURE REVIEW

ETAP is the most comprehensive analysis platform for the design, simulation, operation and automation of generation, distribution, and industrial power system. ETAP is developed under an established quality assurance program and is use worldwide as high impact software. It is completely localized in four languages with translated output reports in six languages. ETAP is the Simulink software where we can draw, configure and analysis a system.

The ETAP software are learn and study from ETAP manual [1] and ETAP power station user guide and also User Define Dynamic model (UDM) studied from Chapter 20 [2].

The power flow analysis and stability analysis has been studied in [3][4] where theory of Electrical Power System, PSS, AVR and governor system has been shown. The calculation of critical clearing time (CCT) which define as the maximum allowable value for clearing time of fault and system remain stable is also illustrated.

The definition of power system stability and its different methods of analysis and control are discussed in [5]. In this book, modelling of PSS, its application and impact on power system stability application has been illustrated with suitable case study and examples.

In [6] modelling of single and as well as multi-machine power system has been shown for small signal stability and transient stability analysis. The detail theory and state variable representation of Power System Stabilizer (PSS) is shown in this reference.

Article [7] studies the transient stability of electrical power system based on the stability of the rotor angle while a three-phase fault, to determine the number of lines to be built under a voltage of 1200 kV and to transport a power of 9000 MW. The simulation is performed using MATLAB/ Simulink software.

A detailed analytical work carried out in [8] to determine the parameters of power system stabilizers for a large generating station. Small-signal and transient stability studies are reported which demonstrate the effectiveness of the stabilizers in enhancing the stability of inter-area as well as local plant models of oscillation.

Ref. [9] covers the transient stability analysis of 400 kV substations. A three phase fault is located at specified bus to analyze the effect of fault location in critical clearing time on the system stability. To stabilize the system load flow analysis is done. The whole simulation has been performed in ETAP.

The IEEE-9 bus test system is simulated and stability is analyzed on ETAP software in [10] Here, fault is created on different busses and transient stability is analyzed for different load and generation conditions. The critical clearing time (CCT) is calculated by using time domain classical extended equal area criterion method. The system frequency and voltage variation is observed for different fault locations and CCT.

1.2 OBJECTIVE OF THE PROJECT WORK

Salient Objectives of this project works are enlisted as follows:

1. Understanding of ETAP software and its use in Power system analysis.
2. Design of single diagram for multi-machine power systems; like 6-bus or 9-bus/Multi-bus power systems.
3. Analysis and study of load flow of the above test power systems.
4. Transient stability analysis of the test power systems by application of typical fault.
5. Study of Power system stabilizer and its application in power system stability analysis.
6. Application of user defined model (UDM) of PSS in transient suability improvement.

CHAPTER 2: Theoretical Overview

2.1 SUMMARY OF ETAP

ETAP stands for Electrical Transient Analysis Program. It is Simulink based software like as MATLAB. A typical power system is designed in this software and then applying any fault or any kind of change in the system it is possible to check the load flow analysis. We can set the fault time, fault clearing time, and observe the transient stability analysis. In ETAP the UDM is also inbuilt, by which we can create individual block-diagram for exciter, PSS, Governor etc..

ETAP is full spectrum analytical engineering software specializing in the analysis, simulation, monitoring, control, optimization and automation of electrical power system. ETAP software offers the best and most comprehensive suite of integrated power system from modelling to operation. It mainly used in generation, transmission, distribution, industrial, transportation, low voltage etc. sectors.

For power generation system critical design and analysis to a smooth operation can be done in ETAP. From renewable to nuclear, some of the world most advance power generation plants also count on ETAP to help and provide reliable, clean and cost-effective power to their customer.

ETAP software mostly used in power transmission system mostly integrated transmission network planning and their protection & energy management solution. ETAP grid transmission system software integrates transmission network planning with their detail substation models, network topology processing, transmission system analysis and real time transmission network energy management system, electric SCADA etc.

ETAP grid offers distribution network analysis operation solution on a progressive geospatial platform for simulating and optimizing the performance of smart grid and micro grid also. It also has practical application on industrial transportation and low voltage area also.

2.2 WHAT IS POWER SYSTEM STABILITY?

Stability—It is defined as its ability to response to a disturbance from its normal operation by returning to a condition when the operation is again normal.

Stability Limit—It is the maximum power transfer through part of the system to which the stability limit refers is operating with stability.

There are three stability state conditions:

1. **Steady-state stability-** Capability to maintain synchronism between machine within the system and external tie lines following a small disturbance (load fluctuation, turbine governor, voltage regulator). Steady state stability limit refers to maximum power which can be transfer through the system without loss of stability.

2. Transient state stability—

Large sudden disturbance is occurred due to fault, clearing of fault, sudden load change and transient stability comes. Maximum power can be transferred through the system without loss of stability under sudden disturbance is referred as transient stability.

3. Dynamic stability—

It is ability of power system to remain in synchronism after initial swing and until the system has settle down to new steady state equilibrium condition. After disturbance, machine rotor is going to swing before governor takes action. Then by governor action the rotor will oscillate until machine fallout from synchronism. It may be happen transient stable but dynamically unstable.

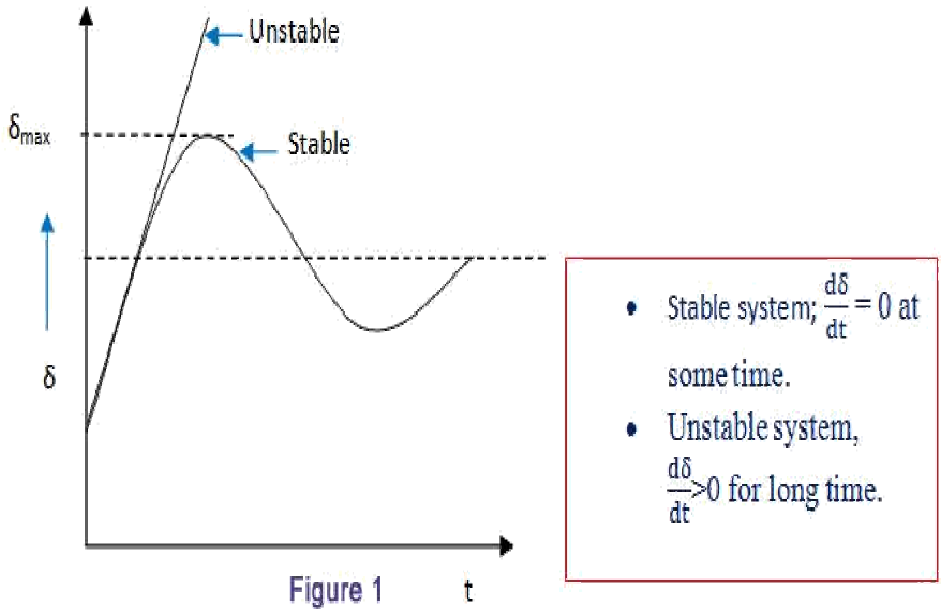


Fig 2.1 Stability Characteristics of Power system (δ : Power angle)

2.3 THEORY OF TRANSIENT STABILITY

Stability study is the procedure for deciding the stability of a system upon some disturbances and this is followed by several switching actions (ON and OFF). In the power system, the behaviour of synchronous machine can have some impacts due to these disturbances. The evaluation of this impact in the stability studies are transient stability studies and steady state stability studies. The steady state stability study refers to whether the synchronism is retained or not when the system is subjected to small disturbances. The transient stability studies implies that whether the synchronism is retained or not when the system is subjected to large or severe disturbances. The disturbances may be a short circuit application or a loss of a sudden large load or a loss of generation.

The objective of transient stability study is to find out whether the load angle comes back to steady value subsequently clearing of the disturbance. Here, non-linear equations are solved to determine the stability. The ***Equal Area Criterion*** is concerned with transient stability. It is in fact a very easy graphical method used. It is for deciding the transient stability of single machine or else two-machine system against infinite bus.

Swing Equation: *The equation gives the relative motion of the rotor with respect to stator field as a function of time is called swing equation.*

For generator $Tag = Ts - Te$

=input torque – output torque

For motor , $Pag = Ps - Pe$

=input power –output power

As angular displacement always varying so its measure is difficult w.r.t synchronously rotating axis-

$$\theta = Ws.t + \partial$$

$$\frac{d\theta}{dt} = \frac{d}{dt}(Ws.t + \partial)$$

$$\frac{d^2\theta}{dt^2} = \frac{d^2\partial}{dt^2} = \alpha$$

$$M\frac{d^2\partial}{dt^2} = Ps - Pe = Ps - Pmax\ \sin\partial$$

Ws—angular velocity of the reference axis rotating synchronously

$$\partial - angular\ displacement\ in\ electrical\ \ degree$$

Equal Area Criterion --- For one machine & infinite

bus or two machine system it is used. It is not applicable for multi-machine system. Main principle is that ∂ oscilates around the equilibrium point with constant amplitude, transient stability maintained.

Swing Equation –

$$M\frac{d^2\partial}{dt^2} = Ps - Pe$$

$$\frac{d\partial}{dt}\left[M\frac{d^2\partial}{dt^2}\right] = \frac{d\partial}{dt}(Ps - Pe)$$

$$\left(\frac{d\partial}{dt}\right)^2 = \int_{\partial 0}^{\partial m} \frac{2(Ps - Pe)}{M} d\partial$$

Before & after disturbance, $\frac{d\partial}{dt} = 0$

$$\int_{\partial 0}^{\partial m} Pa . d\partial = 0$$

1.Pa=o when Pa has accelerating & decelerating power.

So, for generator Ps>Pe; positive area of A1 &Pe>Ps; negative area of A2 for stable operation. It is called equal area criteria.

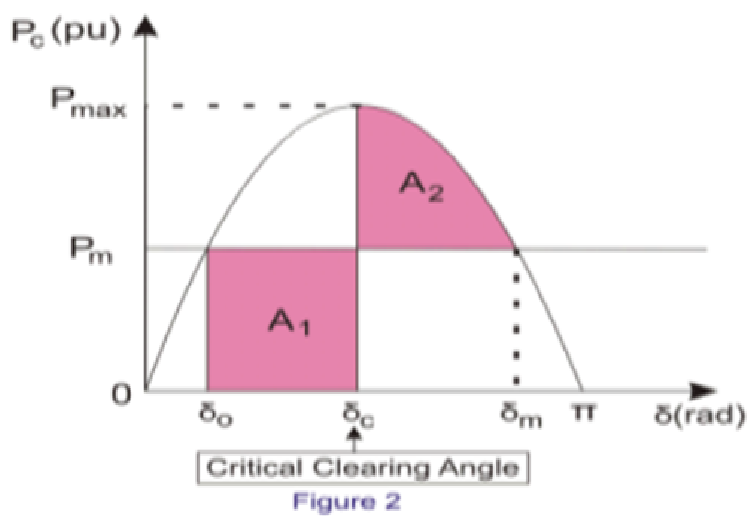


Fig 2.2 : Equal area criterion

1. A1 represents kinetic energy stored by the rotor during acceleration and A2 represents kinetic energy given up by rotor to system and machine comes to its original speed.
2. Main cause to transient stability problem:

a. Sudden change in load, b. Effects of switching operation, c. Faults with subsequent circuit Isolation

2.4 OVERVIEW OF POWER SYSTEM STABIZER (PSS)

PSS are used to control generator which is used in feedback control loop to enhance the damping of rotor oscillation caused due to small signal disturbance due to variation of load and generation. PSS is a ***lead-lag*** compensator. The PSS can take machine speed, frequency or power as input and generate a damping torque in phase with the rotor speed to mitigate rotor oscillation. In electric power system, PSS has the ability to maintain synchronism of all the generators for a given initial condition after being subjected to a physical disturbance.

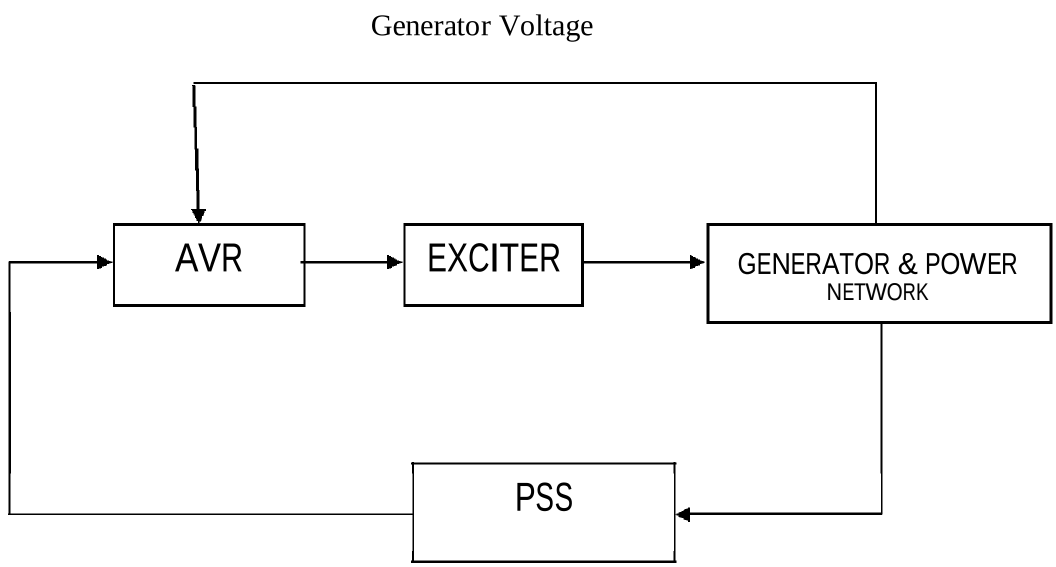


Fig 2.3 Block diagram power system control loop with PSS

This disturbance may be caused by the even small change in the reference voltage of the automatic voltage regulator which results in ever increasing rotor oscillation. The PSS modulates the generator excitation, so as to develop a component of electric torque in phase with the rotor speed derivation to damp out rotor oscillation. The PSS thus contributes to the enhancement of small signal stability of power system.

In this project an used defined model of IEEE PSS is taken into consideration for power system stability analysis. The block diagram of the PSS is shown in the Fig. 2.4

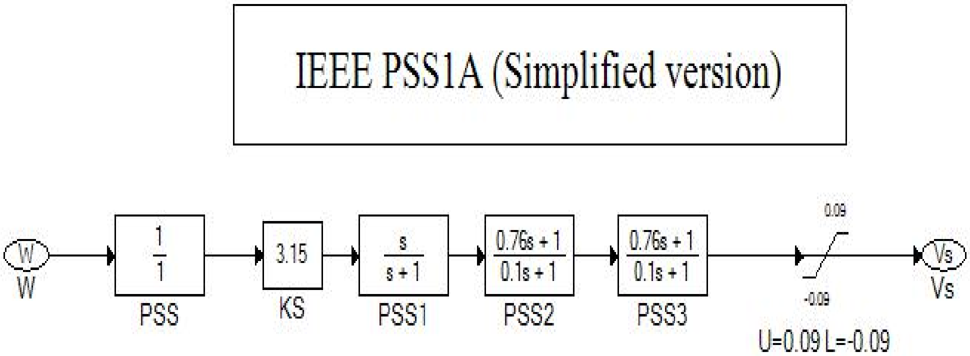


Fig 2.4 Functional block diagram of IEEE PSS 1A

Advantages of application of PSS are;

a. Improve damping system.

b. Dynamic stability of a system is improved.

c. Reduced power losses.

d. Non optimal damping in the entire operating range.

CHAPTER 3: System Study and Implementation

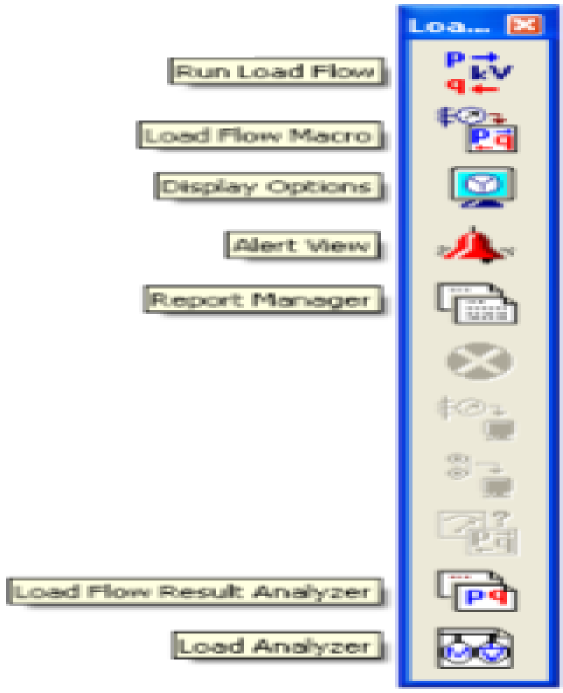
3.1 LOAD FLOW & TRANSIENT STABILITY ANALYSIS STEPS IN ETAP

- **LOAD FLOW ANALYSIS STEPS:**

STEP 1. Click the Load Flow Analysis button on the Mode toolbar to switch to Load Flow Analysis mode.

STEP 2. Running a Load Flow Analysis will generate an output report. In the Study Case toolbar, you can select the name of an existing output report to overwrite, or "Prompt." If "Prompt" is selected, then prior to running the Load Flow Analysis you will be prompted to enter a new report name.

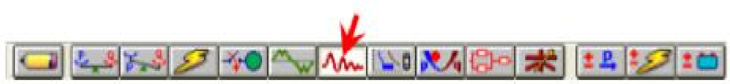
STEP 3. One can customize your study by changing the options in the Load Flow Study Case editor. For example, different methods with maximum number of iterations and precision can be specified; loading and generation categories can be individually selected; load diversity factors can be applied; and finally adjustments can be selected for different elements, e.g. transformer, reactor, overload heater, cable, transmission line, and more.



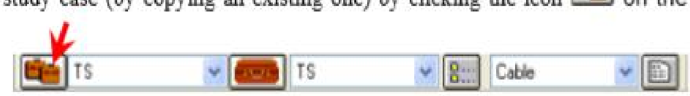
- **TRANSIENT STABILITY ANALYSIS STEPS**

Step 1:

1. Activate the "Study View" one line diagram presentation by clicking its window (or you can go to "project view" and double click "Study View" folder)
2. Switch to Transient Stability Analysis Mode by clicking the icon on the "Mode" toolbar.

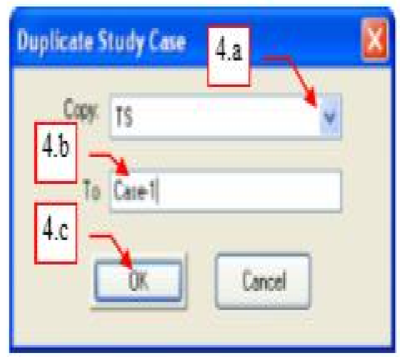


3. Create a new study case (by copying an existing one) by clicking the icon on the "Study Case" toolbar



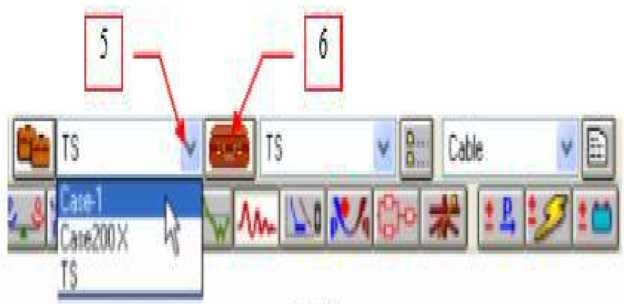
Step 2:

4. The "Duplicate Study Case" dialog box will be displayed as shown in Fig. 1.
   a. Select the existing study case to be copied i.e. "TS".
   b. Enter a unique name for the new study case. Say "Case-1"
   c. Click "Ok" button



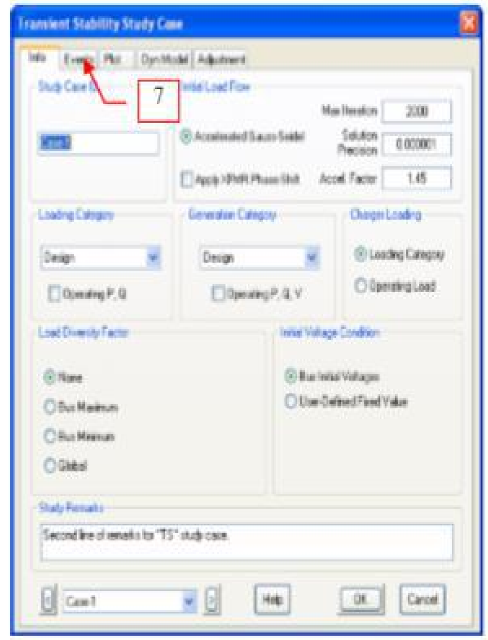
Step 3:

5. Select the study case which was created in Step 4 on the "Study Case" pull down box. See Fig. 2.
6. Click on "Edit Study Case" button to specify the study conditions for "Case-1" study case. See Fig. 2



Step 4:

7. The "Transient Stability Study Case" dialog box will be displayed as shown in Fig. 3. Click the "Events" Tab.



Step 5:

8. On the "Events" tab, existing events and actions will be seen that were inherited from the "TS" study case copied in Step 4. Delete these and create new events and actions based on the illustration on page 2. See Fig. 4

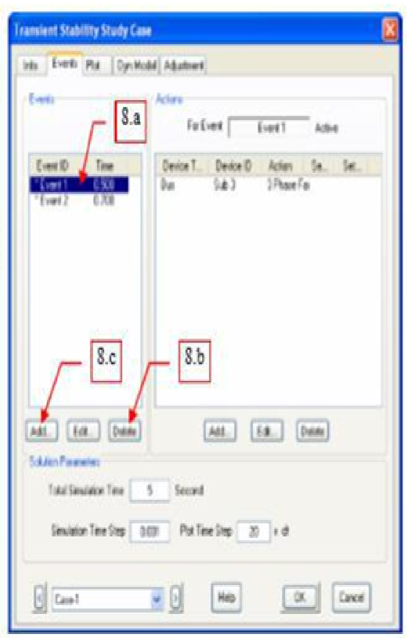
   a. Select "Even1" ID

      Note: Notice that a "*" symbol is prefixed with the ID. The presence of the "*" denotes that the event is active which means that it will be considered during the simulation.

   b. Click "Delete" button

   c. Do similar actions to delete "Event2"

   d. Click "Add.." button. The "Event Editor" dialog box will be displayed.



9. On the "Event Editor" dialog box shown in Fig. 5, do the following:

   a. Type "E1" on the "Event ID" text box

   b. Type "0.5" on the "Time" text box

      Note: 0.5 is the time in second at which the event occurs.

Step 6:

c. Click the "OK" button

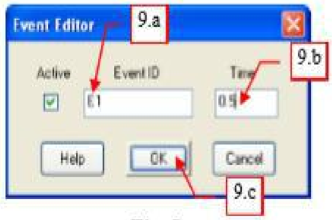
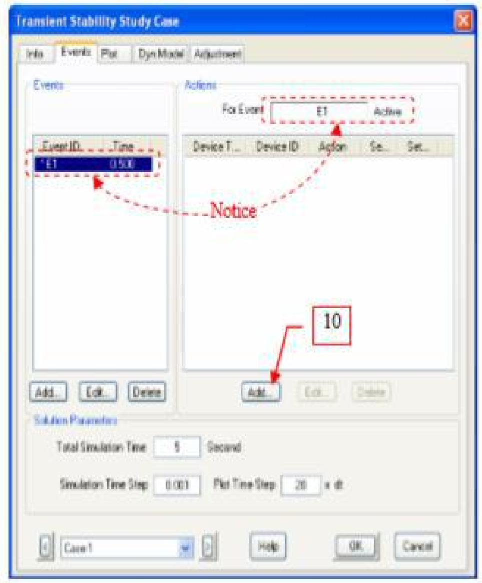


Fig. 5

10. With the Event ID "E1" active (selected) on the "Events" Frame of the "Events" dialog box, click the "Add" button at the "Actions" frame (See Fig. 6). The "Action Editor" dialog box will be displayed.



Step 7:

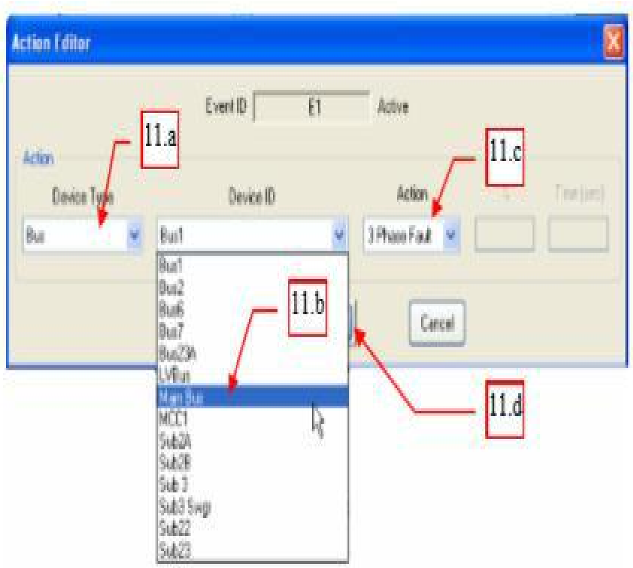
11. As per the Illustration on page 2, do the following on the "Action Editor" dialog box shown in Fig. 7:

a. Select "Bus" on the "Device Type".

b. Select "Main Bus" on the "Device ID".

c. Select "3PhaseFault" on the "Action.

d. Click "OK" button.



Step 8:

12. Follow Step 9 to add the second event with the following data:

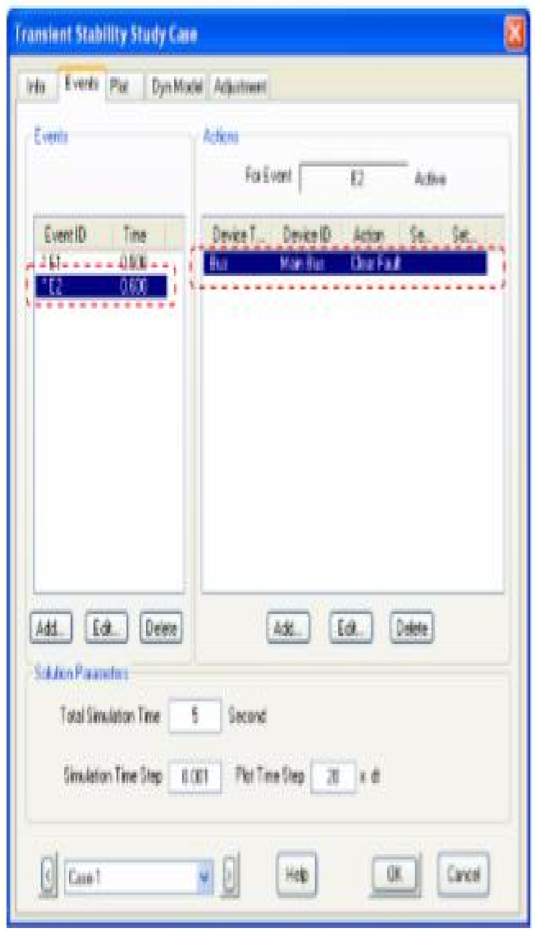
    Event ID → E2
    Time → 0.6 sec

    Note: For the time, we specified 0.6 second since as per the Illustration on page 2; the fault will be cleared after 0.1 sec. Since E1 will occur at 0.5 sec, E2 must occur at 0.6 sec to get a difference of 0.1 sec fault clearing time.

13. Associate an action to event "E2" by following Steps 10 and 11. At the "Action Editor" dialog box, select the following:

    Device Type → Bus
    Device ID → Main Bus
    Action → Clear Fault

    The end result should look like Fig. 8



14. For this particular exercise, maintain the existing setting on the "Solution Parameters" frame.

    Explanation of the parameters:

    Total Simulation Time – The period in second to be considered in the simulation. This time should be greater than the time of the last event.

    Simulation Time Step – The integration time step in the simulation. The program performs calculation at every interval of this time step.

    Plot Time Step – This is the interval in multiple of the Simulation Time Step at which ETAP records the results of the calculation. This determines the

Step 9:

15. Since the concern is to verify the response of the Gen1 due to the disturbance, instruct the program to create plot profiles for the Gen1. See Fig. 9.

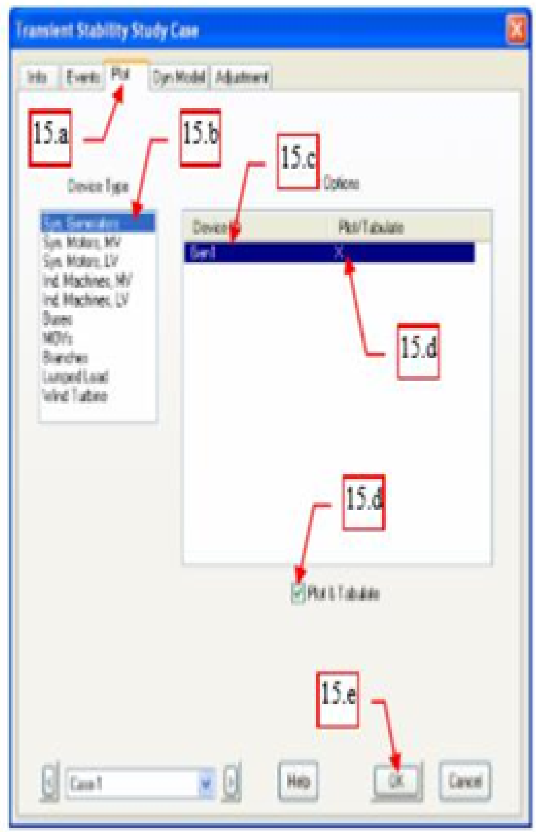
    a. Click the "Plot" tab.

    b. On the "Device Type", select "Syn Generator".

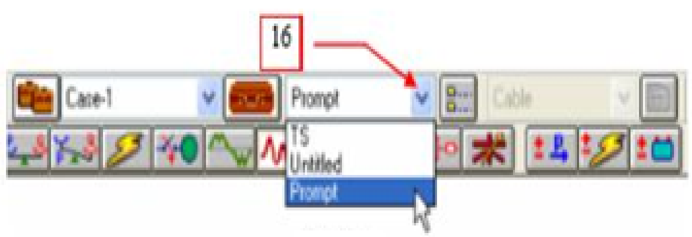
    c. On the "Plot Options" select "Gen1".

    d. Click the "Plot & Tabulate" check box to leave a check mark, or just click directly at the "Plot/Tabulate" column adjacent to "Gen1"

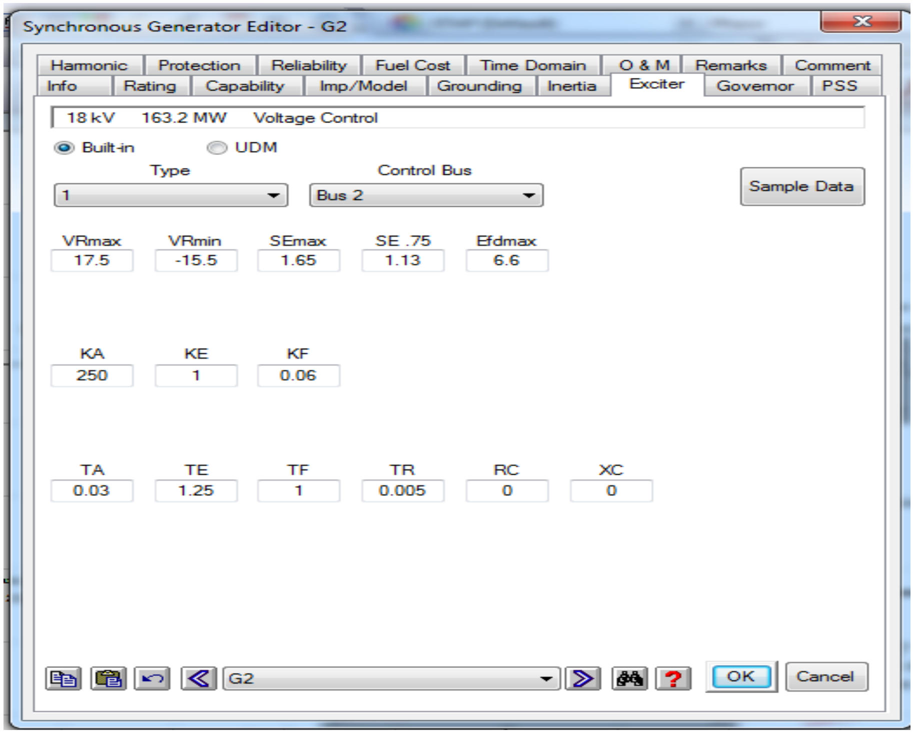
    e. Click "OK" button to close the study case.



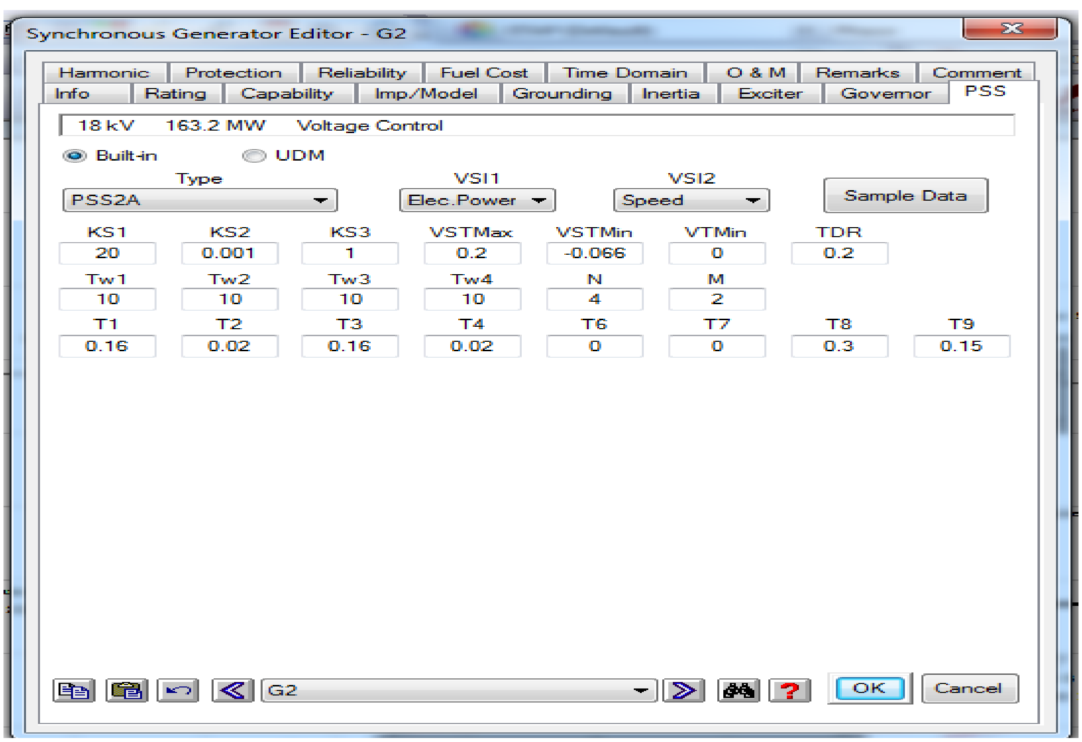
16. Now, run the simulation. On the "Study Case" toolbar, select "Prompt" from the "Output Report" pull down box. The program will prompt for a filename of the output report for the study case "Case-1" when the simulation is ran. See Fig. 10.



Step 10:



Step 11:



Step 12:

17. On the "Transient Stability" toolbar, click "Run Transient Stability" button, see Fig. 11.

18. The "Output Report Filename" dialog box will be displayed (due to Step 16) as shown below. Type "R-Case1" and click "OK" button. The program will proceed with the calculation.

3.2 Configuration of single-line diagram for 6-bus system:

A 6-bus multi-machine system has been designed to study the load flow and transient stability analysis. The Load flow and transient stability performance of the system has been studied without application of PSS. The results of load flow analysis are presented below.

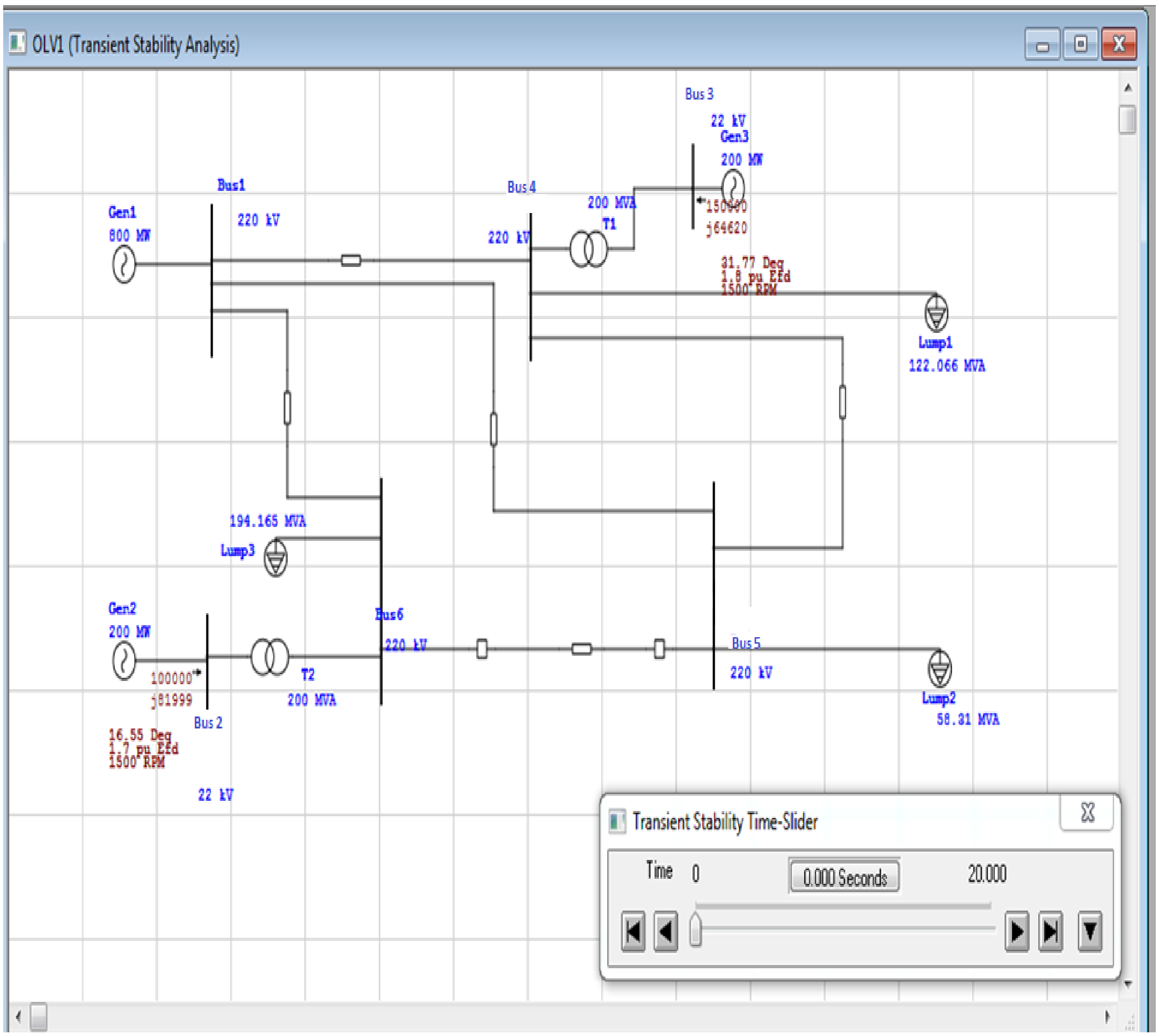


Fig. 3.1 Schematic diagram of 6-bus system

3.3 Load flow results of 6-bus system

Table 3.1 Load flow report of 6-bus system

LOAD FLOW REPORT

Bus	Voltage			Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
*Bus1	220.000	106.000	0.0	62.103	79.706	0	0	Bus4	-7.931	17.838	48.3	-40.6	
								Bus6	52.446	38.753	161.4	80.4	
								Bus5	17.589	23.115	71.9	60.6	
*Bus2	22.000	103.000	-1.1	100.000	81.999	0	0	Bus6	100.000	81.999	3294.9	77.3	
Bus4	220.000	100.990	-2.4	0	0	160.000	110.000	Bus1	-51.495	-35.243	162.2	82.5	
								Bus5	-8.583	3.302	23.9	-93.3	
								Bus3	-99.921	-78.059	329.5	78.8	
Bus6	220.000	102.423	1.3	0	0	100.000	70.000	Bus1	8.054	-17.755	50.0	-41.3	
								Bus5	41.799	6.211	108.3	98.9	
								Bus2	-149.853	-58.456	412.1	93.2	
Bus 5	220.000	100.621	-1.5	0	0	50.000	30.000	Bus1	-17.283	-22.060	73.1	61.7	
								Bus4	-41.322	-4.441	108.4	99.4	
								Bus6	8.605	-3.499	24.2	-92.6	
*Bus 3	22.000	104.000	3.3	150.000	64.620	0	0	Bus 4	150.000	64.620	4121.4	91.8	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

# Indicates a bus with a load mismatch of more than0.1 MVA

3.4 Stability analysis of 6-bus system

The response of generator absolute power angle, relative power angle and the generator speeds are investigated for a simulation time 20 Sec. It has been observed that in all cases responses are stable.

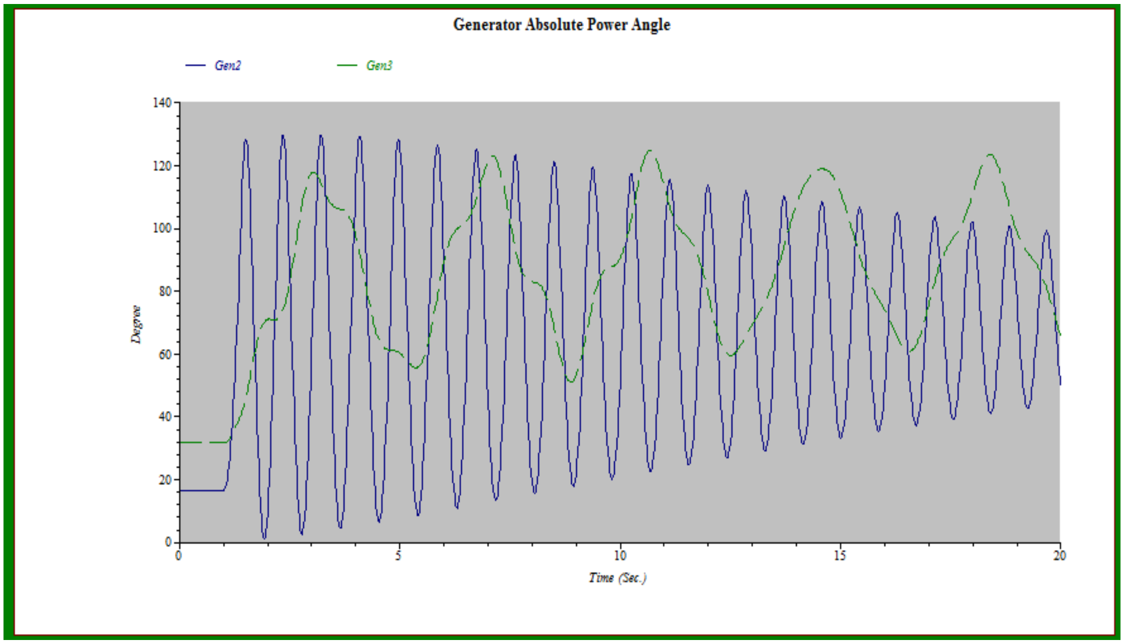


Fig. 3.2 Absolute Power angle vs Time

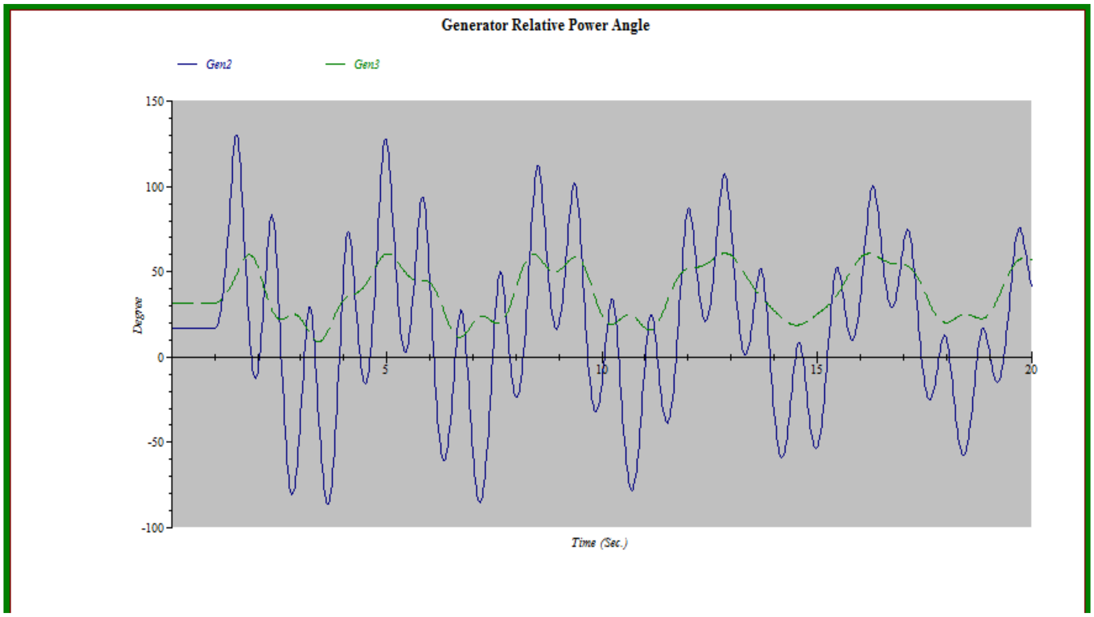


Fig.3.3 Relative Power angle vs Time

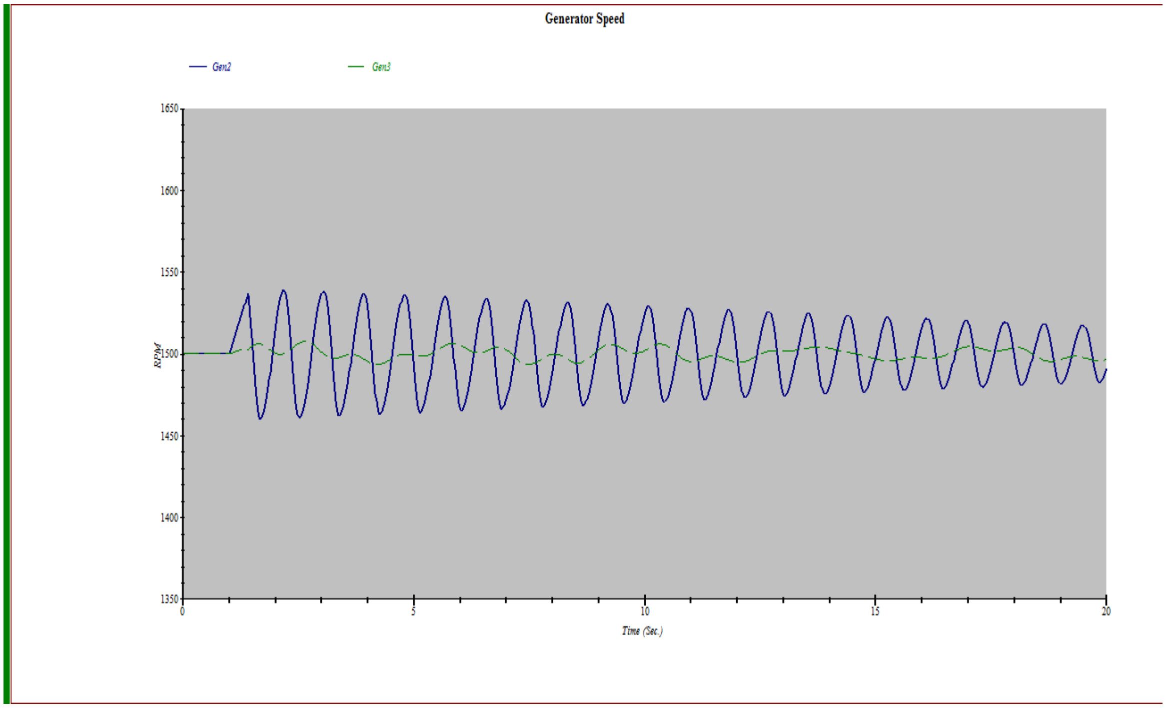


Fig.3.4 Generator Speed vs Time

3.5 Schematic diagram of proposed 9-bus multi machine system

A 9-bus multi-machine system has been configured to study the load flow and transient stability analysis. A user define model of PSS is to be incorporated with a specific generator bus to improve the transient stability performance of the system. It has been seen that without PSS the response of the system parameters are oscillatory and some cases unstable in nature. However, with the application of PSS oscillatory nature of the parameters has been reduced and reaches stable and steady state position.

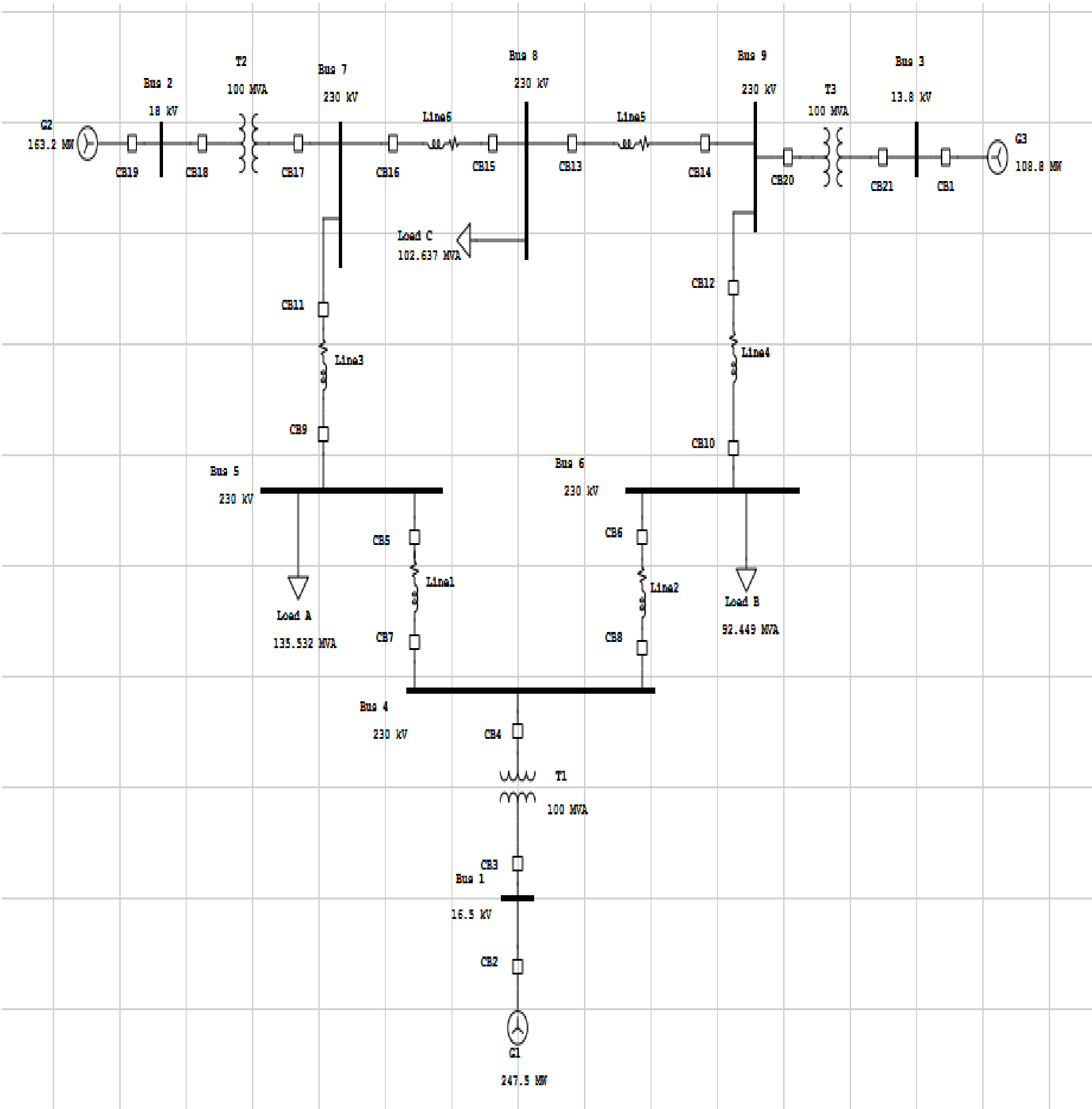


Fig 3.5: Schematic diagram of 9-bus system

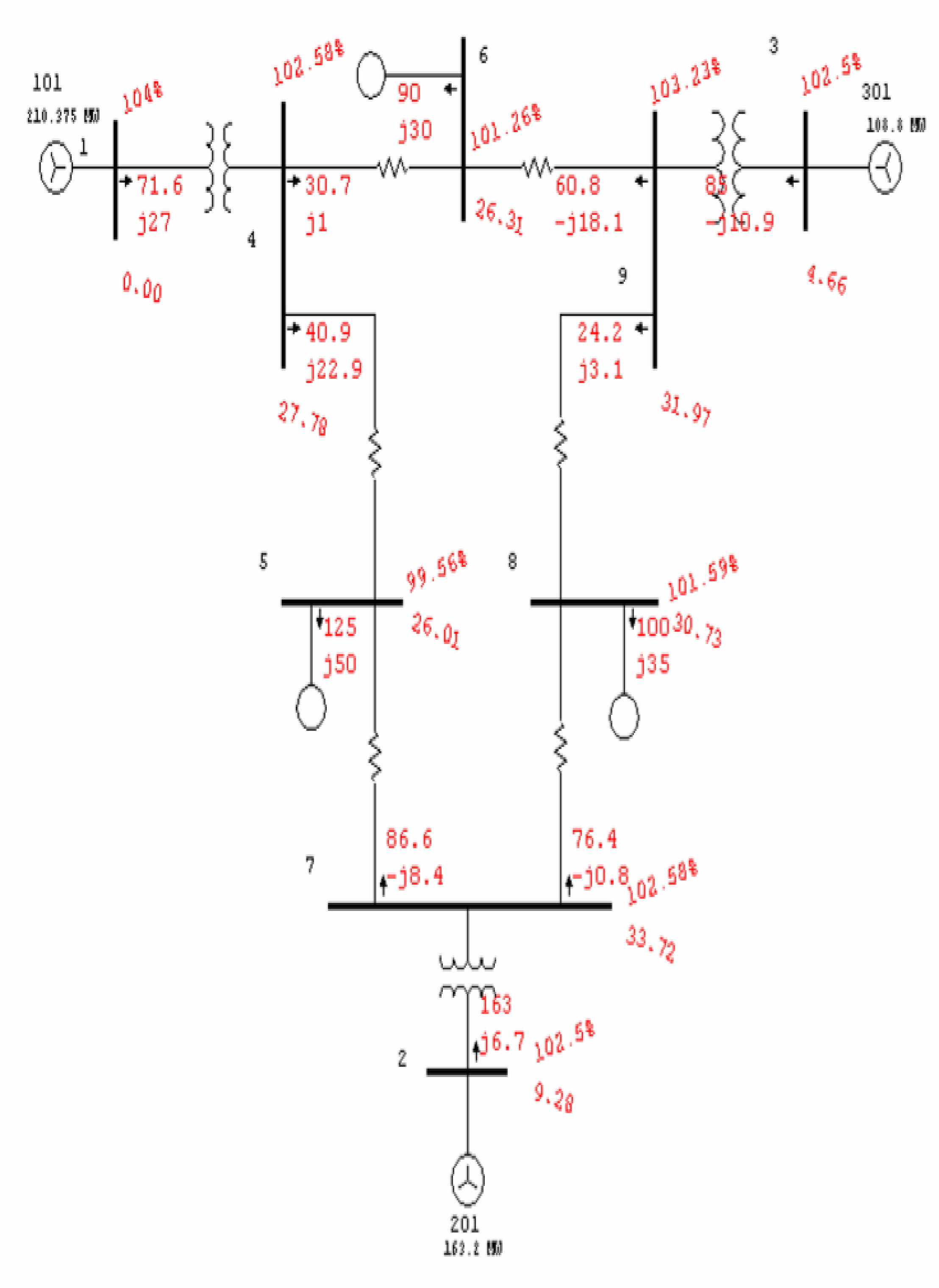


Fig. 3.6 Schematic diagram of 9-bus system with Load flow results

3.6 Load flow results of 9-bus system

Results of load flow study of the 9-bus system are presented in the Table 3.2. In Load Flow Report, it has been observed that the bus voltages are increased by 4% , 2.5% , 2.5% , 2.57% , 1.2% , 2.5% , 5.8% ,2.3% in Bus no 1 , Bus no 2 , Bus no 3, Bus no 4, Bus no 6, Bus no 7 , Bus no 8 , Bus no 9 respectively and decreased by 0.5% in Bus no 5.

Table 3.2 Load flow report of 9-bus system

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
* Bus 1	16.500	104.000	0.0	71.337	26.963	0	0	Bus 4	71.337	26.963	2565.9	93.5	
* Bus 2	18.000	102.500	9.3	163.000	6.562	0	0	Bus 7	163.000	6.562	5104.8	99.9	
* Bus 3	13.800	102.500	4.7	85.000	-10.885	0	0	Bus 9	85.000	-10.885	3497.7	-99.2	
Bus 4	230.000	102.579	-2.2	0	0	0	0	Bus 5	40.716	22.829	114.2	87.2	
								Bus 6	30.618	1.037	75.0	99.9	
								Bus 1	-71.334	-23.866	184.1	94.8	
Bus 5	230.000	99.570	-4.0	0	0	124.761	49.895	Bus 4	-40.460	-38.642	141.1	72.3	
								Bus 7	-84.301	-11.253	214.4	99.1	
Bus 6	230.000	101.266	-3.7	0	0	89.939	29.980	Bus 4	-30.453	-16.556	85.9	87.9	
								Bus 9	-59.487	-13.424	151.2	97.5	
Bus 7	230.000	102.573	3.7	0	0	0	0	Bus 5	86.600	-8.450	212.9	-99.5	
								Bus 8	76.384	-0.819	186.9	100.0	
								Bus 2	-162.984	9.269	399.5	-99.8	
Bus 8	230.000	101.585	0.7	0	0	99.975	34.977	Bus 9	-24.066	-24.295	84.5	70.4	
								Bus 7	-75.909	-10.683	189.4	99.0	
Bus 9	230.000	103.232	2.0	0	0	0	0	Bus 6	60.842	-18.099	154.4	-95.8	
								Bus 8	24.154	3.117	59.2	99.2	
								Bus 3	-84.996	14.981	209.9	-98.5	

3.7 Study of transient stability characteristics of the 9-bus system

In transient stability study of the 9-bus system, the speed and absolute power angles of the Generators 2&3 are simulated for 5 sec. It has been found that response have oscillation and unstable in nature and monotonically increasing. After applying PSS, it has been observed that speed of the Generators become stable within 5 sec but absolute power angle remaining stable up to 3.8 sec, and thereafter losses its stability.

Output response without PSS:

Fig 3.7 Generator Speed vs Time (sec)

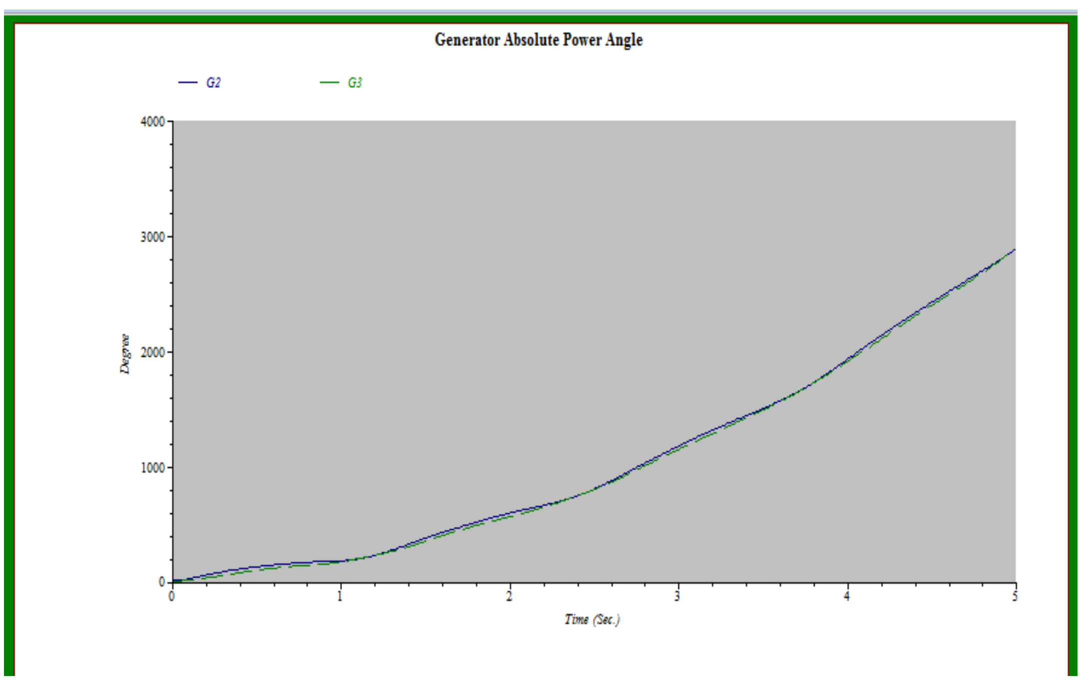


Fig 3.8 Generator Absolute Power Angle vs Time (sec)

3.8 Application of PSS in 9-bus system:

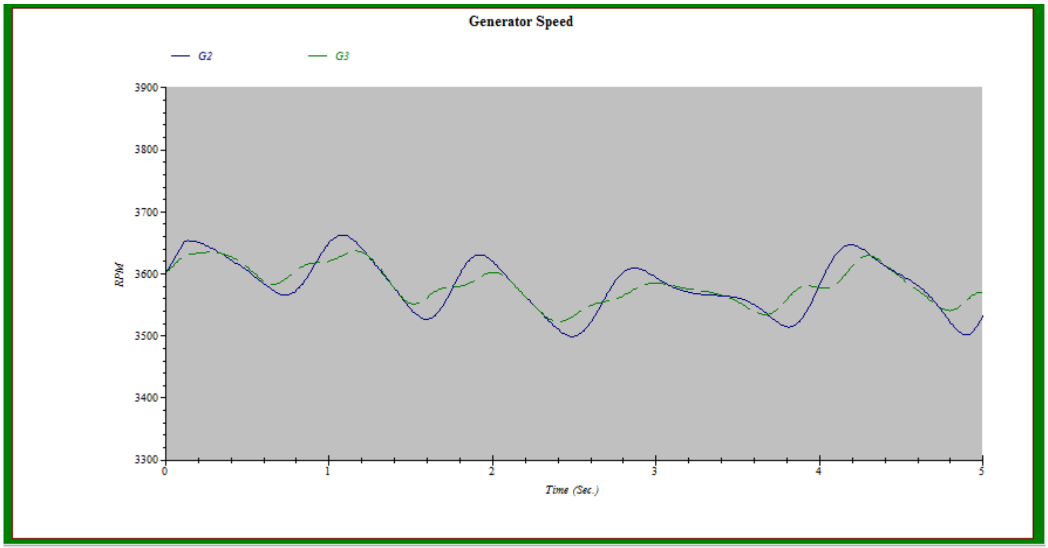


Fig. 3.9 Generator Speed vs Time (sec)

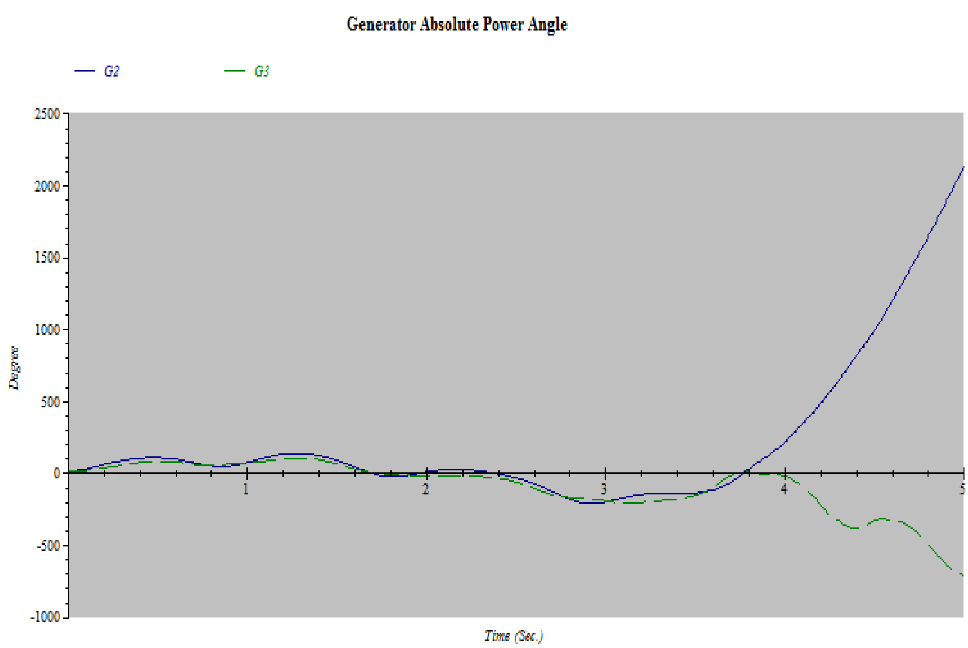


Fig 3.10 Generator Absolute Power Angle vs Time (sec)

CHAPTER 4: Conclusion & Future Scope of work

4.1. CONCLUSIONS

In this project the power flow and transient stability analysis has been performed on ETAP software. A 6-bus and 9-bus study system has been taken into consideration to study the load flow & transient stability characteristics of the system. Performance of the system has been investigated for typical false scenarios. A PSS is incorporated with a specific generator bus to improve the transient stability performance of the system. The simulation has been carried out for the parameters; generator speed, generator relative power angle, bus voltage, bus voltage angle without and with PSS. It has been observed that without PSS the response of the system parameters is oscillatory and some cases unstable in nature due to the effect of fault. However, with application of PSS oscillatory nature of the parameters are reduced and reaches stable and steady state position. PSS not only reduces overshoot and undershoot in response but also quickly brings the system

4.2 FUTURE SCOPE

The future scopes of this work are:

(i) Verification of the ETAP model in real time application and also verification of the protection relay setting and co-ordination study.

(ii) Voltage stability analysis can be performed for the designed multi-machine model.

(iii) Arc flash study can be implemented.

(iv) The study can be made for higher no. of bus systems like IEEE-14 bus or IEEE-30 bus systems.

(v) Short circuit analysis and hence stability can be investigated.

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