Power System Stability Analysis By Applying PSS in ETAP

A Project report submitted in partial fulfillment

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

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CERTIFICATE

To whom it may concern

This is to certify that the project work entitled," **Power System Stability Analysis Applying PSS In ETAP**" is the bona fide work carried out by **Pranay Paria (11701615064), Sarbamangala Ray (11701615066), Somnath Paul (11701615068), Sayantan Choudhury (11701614040)** 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 2017-18, in partial fulfillment 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

Name:

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.

I wish to convey my gratitude to Prof. (Dr.) Alok Kole, HOD, Department of Electrical Engineering, RCCIIT and to the authority of RCCIIT for providing all kinds of infrastructural facility towards the research work.

I would also like to convey my gratitude to all the faculty members and staffs of the Department of Electrical Engineering, RCCIIT for their whole-hearted cooperation to make this work turn into reality.

Name and Signature of the Student

Place:

Date:

Abstract

This paper proposes Power System Stabilizer (PSS) in addition to the existing AVR and Governor for Power System Stability. The variations of rotor angle, voltage and frequency comparison parameter. The system is simulated with the existing for three phase fault and single phase fault using ETAP software. The combination of AVR, Governor and PSS maintains synchronism during all kind of faults.

Electric power system stability analysis has been recognized as an important and challenging problem for secure system operation. When large disturbances occur in interconnected power system, the security of this power system has to be examined. Power system security depends on detailed stability studies of system to check and ensure security. In order to determine the stability status of the power system for each contingency of any disturbance occurs in power system.

Power system stability analysis may involve the calculation of critical clearing time (CCT) for given fault which is defined as the maximum allowable value of the clearing time for which the system remains to be stable. The power system shall remain stable if the fault is cleared within this time. However, if the fault is cleared after the CCT, the power system is most likely to become unstable. Thus, CCT estimation is important tusk in the transient stability analysis for a given contingency.

Critical clearing time (CCT) in a way measure the power system transient stability. It denotes the secure and safe time margin for clearing the contingency, usually three phase ground fault. The larger value of CCT, the power system has sample time to clear the contingency. CCT depends on generator inertias, line impedances, grid topology and power system operating conditions, fault type and location. For a single machine infinite bus power system, CCT calculation is straight forward. While for the case of multi machine power system CCT is always obtained by repeating time domain simulation.

CHAPTER 1: Introduction:

1.1:LITERATURE REVIEW:

Normally power system is running with stabilized operation. When sudden change in load any kind of earth fault occurs then the stabilization comes to the system. Basically, stabilization means the change in angle between stator and rotor angle & also the change in speed of the machine.

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 a 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 a system. By using Power System Stabilizer, we can reduce the instability by providing signal to rotor.

In the given project, “Power System Stability Analysis by Applying PSS in ETAP” we study the whole project work from different references. These are-

The abstract are help from C. L. Wadha , “Electrical Power System” where the PSS are existing AVR and governor for power system stability and the system is simulated #phase and 1 phase fault by using ETAP. The PSS analysis may involve the calculation of critical clearing time (CCT) which define as the maximum allowable value for clearing time of fault and system remain stable.

The whole ETAP software are learn and study from “ ETAP power station user guide” and also User Define Dynamic model(UDM) studied, chapter 20.

The Power System Stability Analysis and Control are studied and guided us about PSS from- P. Kundur, “Power System Stability & Control”, Mc Graw Hill.inc

The schematic diagram are inbuilt in the ETAP software and we analysis the transient stability of synchronous generation related this project from F. Selwa, L. Djmel, “Transient Stability Analysis of Synchronous Generation of Electrical Work”.

The study of overall project with help of ETAP manual, ETAP AUTOMATION PRIVATE LTD INDIA its available at RCCIIT, EE, APJ Abdul Kalam Inovation Centre.

1.2:OBJECTIVE OF THE PROJECT WORK:

The main objective of PSS is to damp out oscillations, it can have strong effect on power system transient stability. As, PSS damps oscillation by regulating generator field voltage it results in swing of VAR output. So the PSS gain is chosen carefully, so that the resultant gain margin of volt/VAR swing should be acceptable. A control enhancement may be needed during the loading/unloading or loss of generation when large fluctuations in the frequency and speed may act through the PSS and drive the system towards in stability. A modified limit logic will allow this limits to be minimized while ensuring the damping action of PSS for all other system events.

Another aspects of PSS which needs attention is possible interaction with other controls which may be part of the excitation system or external system. Apart from the low frequency oscillation the input of PSS also contains high frequency turbine generator oscillation which should be taken into account for the PSS design. So emphasis should be on the study of potential of PSS-torsional interaction and verify the conclusion before commission of PSS.

CHAPTER 2: Theoretical Overview

2.1:SUMMARY OF ETAP:

ETAP stands for Electrical Transient Analysis Program. It is Simulink base software like as MATLAB. A system is designed into the software and then if any fault or any kind of change occurs into the system then we check the load flow diagram. After implementing the system, we have to set the fault time, fault clearing time, and we see the transient stability analysis. In ETAP the UDM is inbuilt, by which we create individual block diagram for exciter, PSS, governor.

ETAP is a 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 modeling 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. From renewable to nuclear, some of the world most advance power generation plants count on ETAP to help 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 there 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 practical application on industrial transportation and low voltage area also.

2.2: THEORY OF TRANSIENT STABILITY ANALYSIS:

Stability—Itis 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 condition—

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 governor action the rotor will oscillation until machine fall out from synchronism .It may be happen transient stable but dynamically unstable.

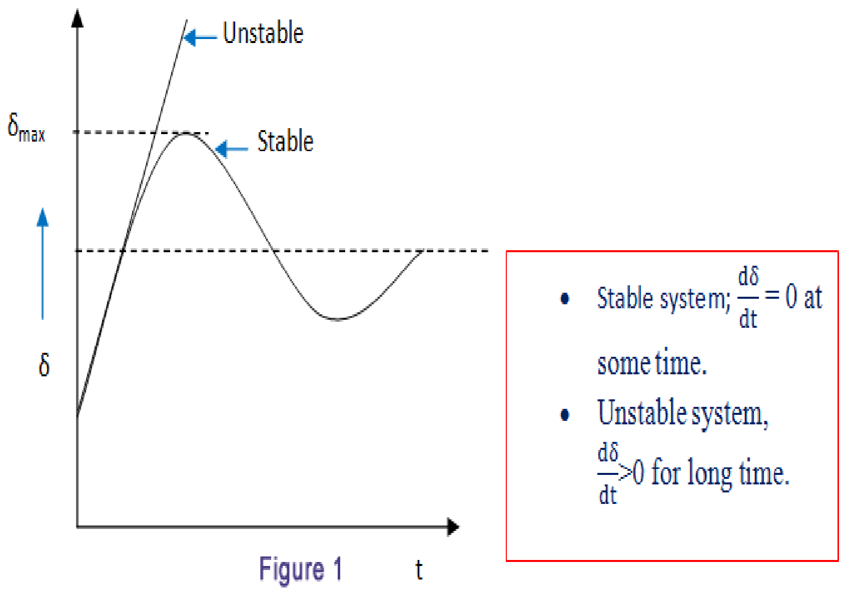


Fig 2.2.1: Characteristics of stability vs time

At first we have to know about power stability study. 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 behavior 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.

These disturbances may be a short circuit, application or a loss of a sudden large load or a loss of generation. The objective of this 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 –

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

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

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

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.

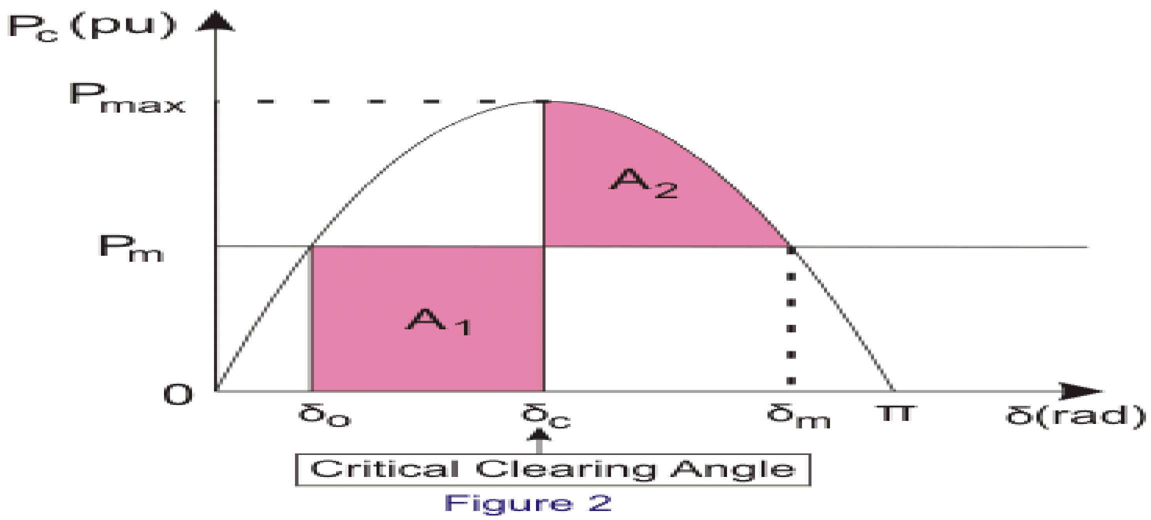


Fig 2.2.2: Equal area criterion

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

2.3:OVERVIEW OF PSS:

Power system stabilizer is an ability of an electric power system, for a given initial condition, a star operating equilibrium after being subjected to a physical disturbance, with most system variable, bounded so that practically the entire system remain intact.

PSS are used ton generator control which are used in feedback to enhance the damping of rotor oscillation caused due to small signal disturbance.

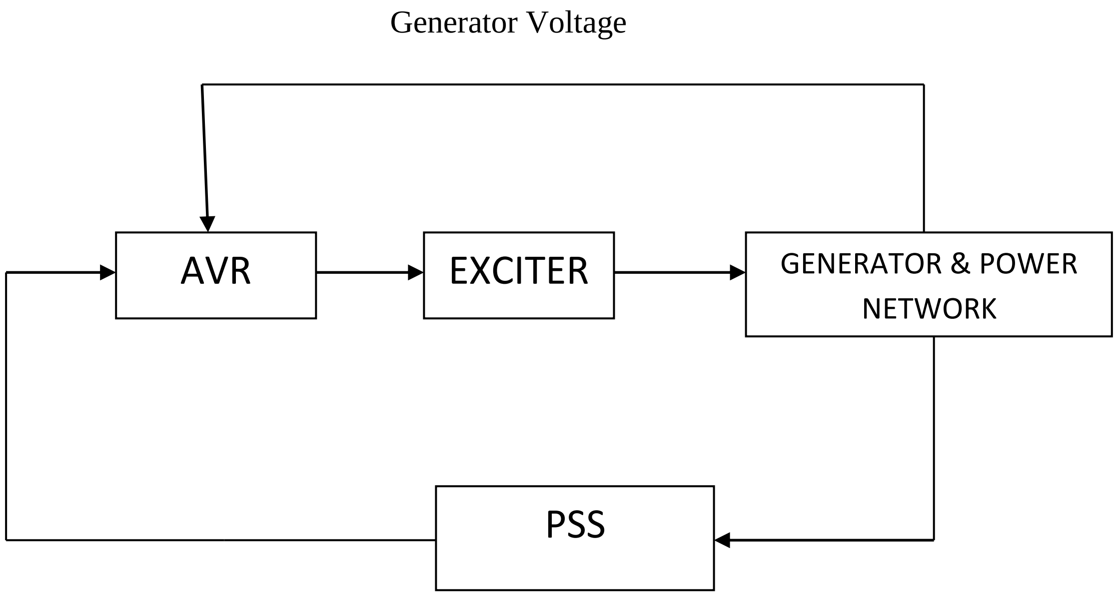


Fig 2.3.1: PSS block diagram

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 .this is achieved by modulating the generator excitation ,so as to develop components of electric torque in phase with rotor speed derivation . the PSS thus contributes to the enhancement of small signal stability of power system.

FUNCTIONAL BLOCK DIAGRAM OF PSS:

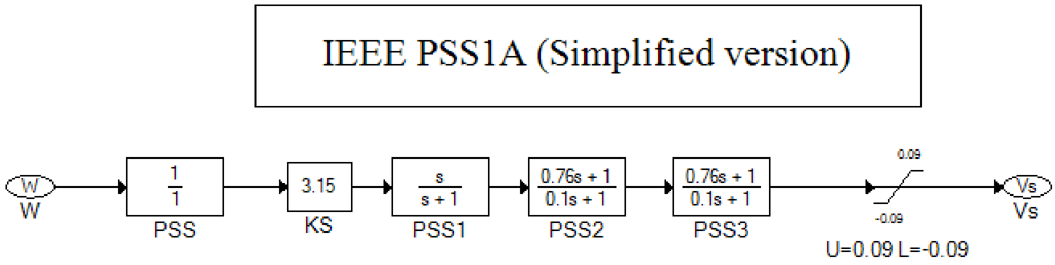


Fig 2.3.2: Functional block diagram of IEEE PSSA

Advantage

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.

2.4:OVERVIEW OF UDM:

UDM stands for User Defined Dynamic Models. It has three steps for completing the work. It is the tools to link up defined governor, exciter, PSS. The steps are-

A. Create UDM template file.
B. Create UDM equation file.
C. Power system transient stability models.

Using block diagram first make the models of individuals, then save it and change the parameter. After compiling the models of UDM equation will be generate. When we build a system any power station then we see the transient characteristics.

Custom Block Diagram Of UDM

A. Automatic voltage regulator(AVR)
B. Power system stabilizer(PSS)
C. Generator exciter
D. Turbines/Engines
E. Speed governors/Controllers
F. Photovoltaic array

UDM Capabilities

A. Transient stability
B. Generator start-up
C. Motor acceleration
D. Synchronous motor start up
E. Frequency dependent models
F. Bus voltage support mode

CHAPTER 3: System Study and Implementation

3.1: SCHEMATIC DIAGRAM OF PROPOSED SYSTEM:

In this system four bus system from network feeder 33KV line comes to utility bus. Then it separates into two lines. One line goes to 15MVA transformer where voltage step down to 11KV. Another line goes to 3phase winding transformer 10-5-5MVA and steps down at 11KV. It has tertiary winding then it gives supply two bus through circuit breaker. 3.5MW generator also power supplies to bus A through transformer OCB the power feeds to 11KV bus.

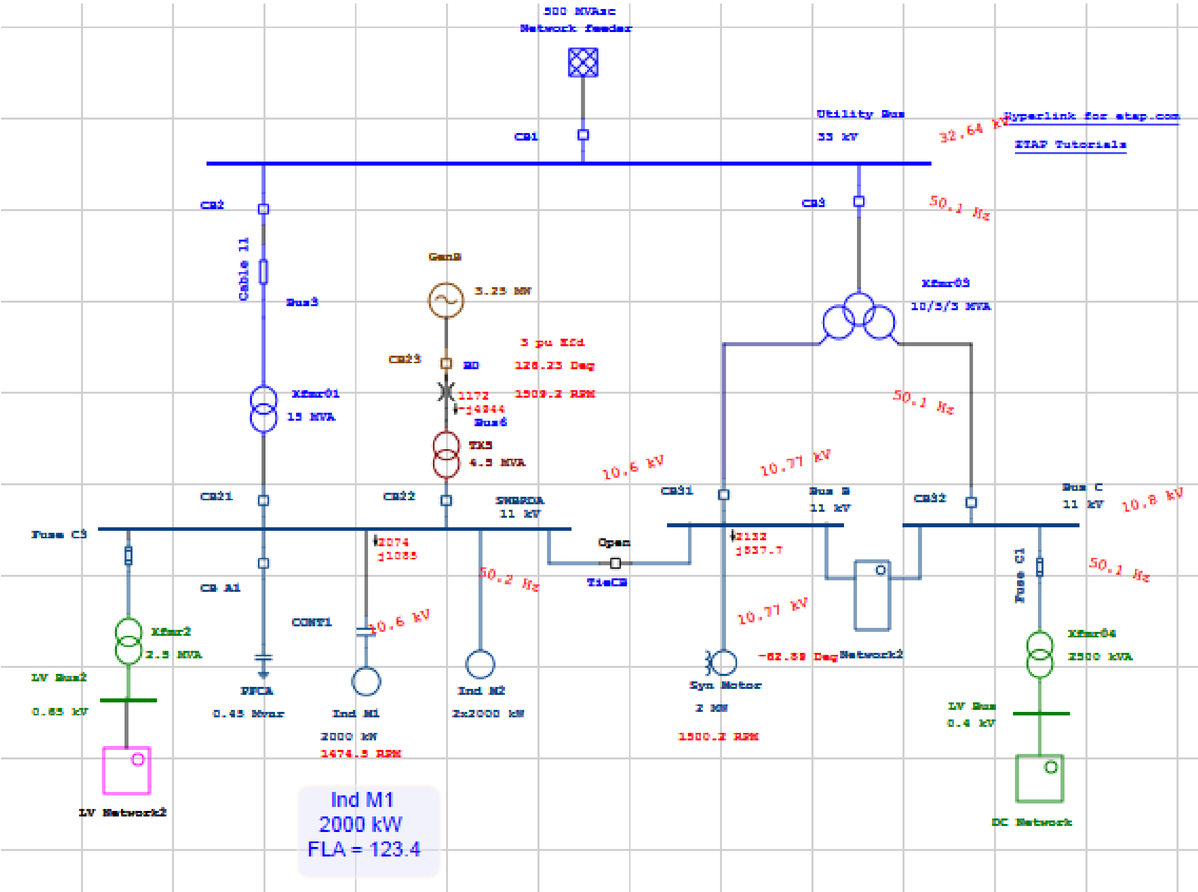


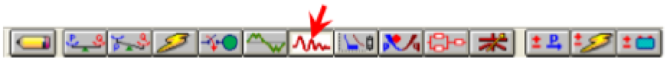
FIG 3.1.1: Schematic diagram of 4bus system

From bus A one line goes into 2.5MVA and step down to 0.65KV LV bus. Second line goes for power factor correction. Third & fourth line goes to induction motor 1 and 2. Bus A and B are tied up by circuit breaker and also bus B tied up with bus C. From bus B DYL motor 2MW get supply. Bus C connects to 2500KVA transformer and step down into 0.4KV for four bus system.

3.2:TRANSIENT STABILITY ANALYSIS STEPS IN ETAP:

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

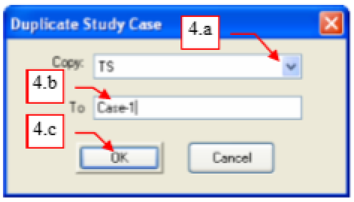


Fig. 1

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

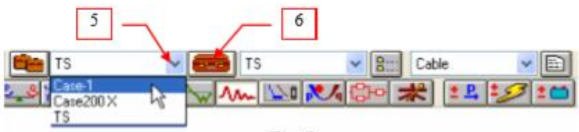


Fig. 2

Step 4:

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

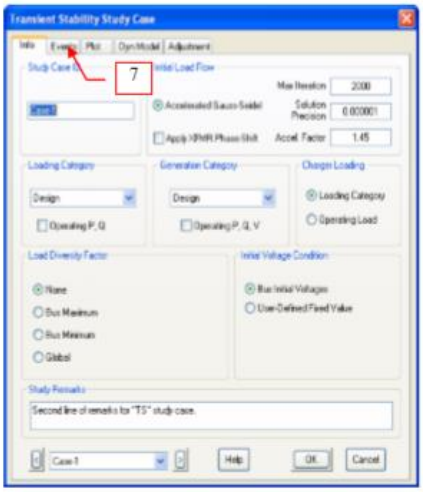


Fig. 3

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.

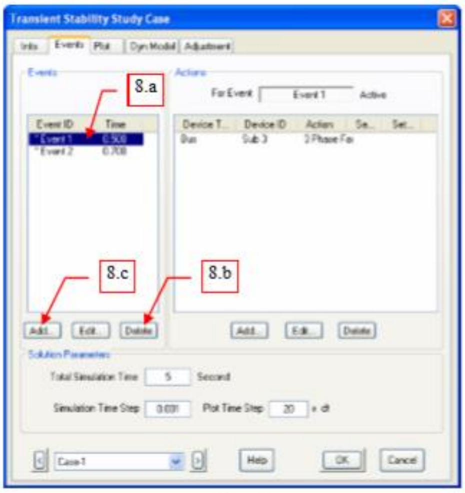


Fig. 4

Step 6:

c. Click the "OK" button

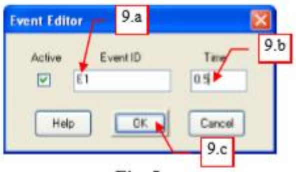


Fig. 5

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.

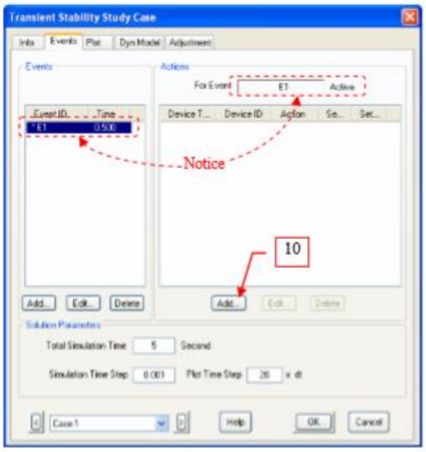


Fig. 6

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.

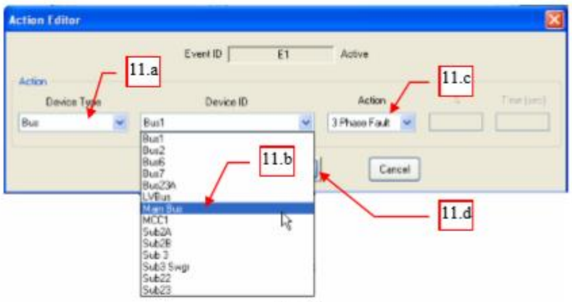


Fig. 7

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 resolution of the output Plots (graphs).

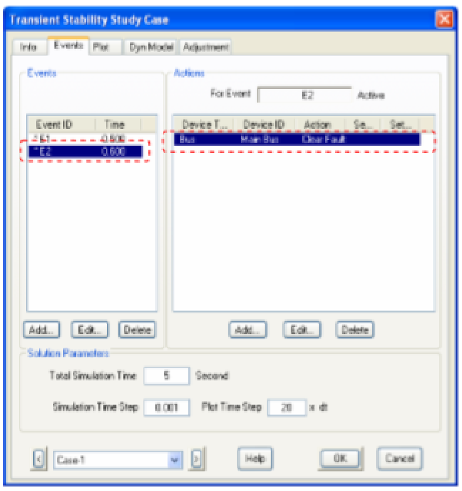


Fig. 8

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.

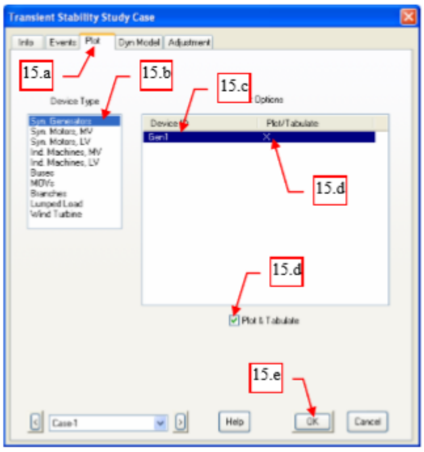


Fig. 9

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.

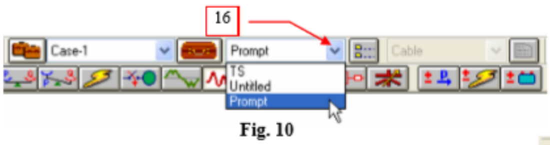
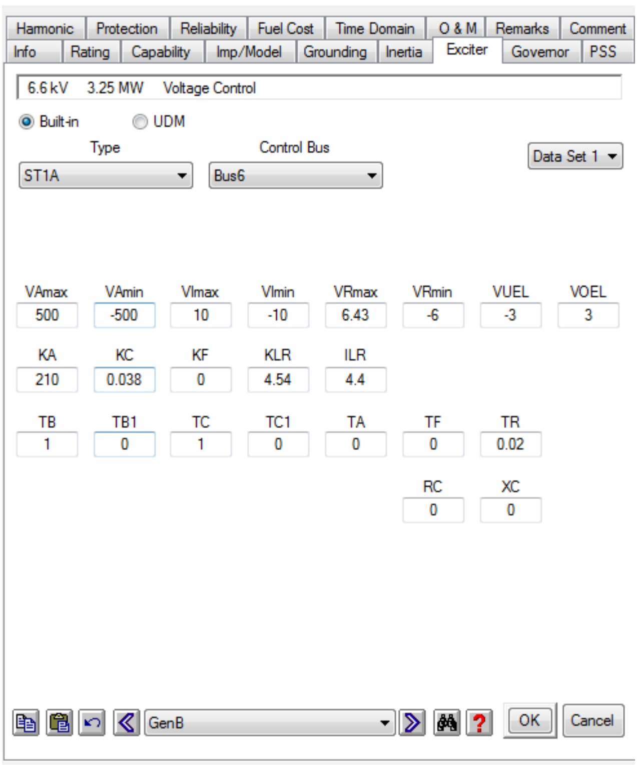
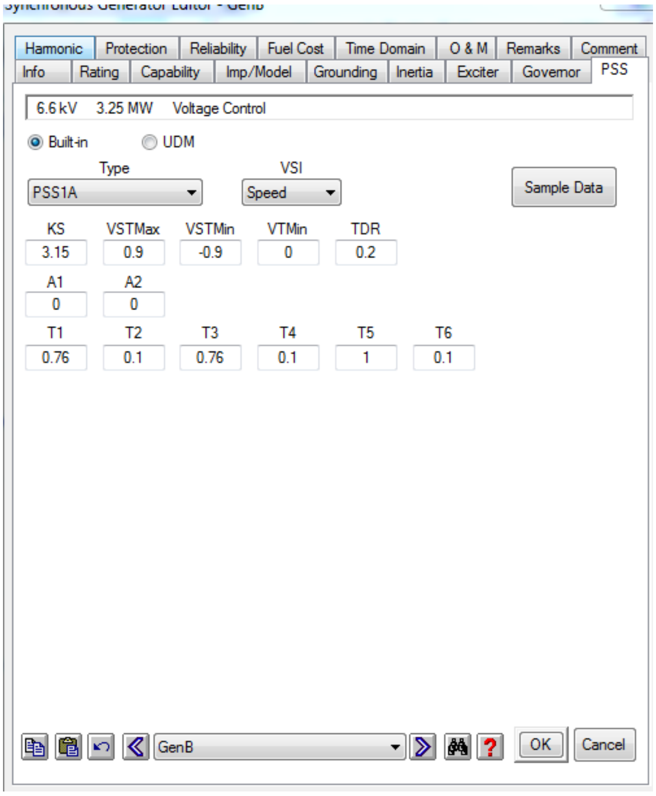


Fig. 10

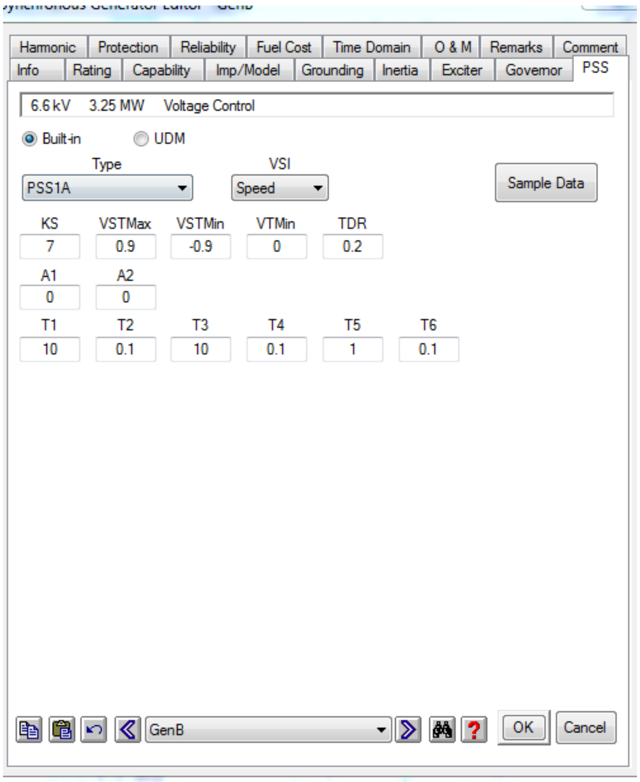
Step 10:



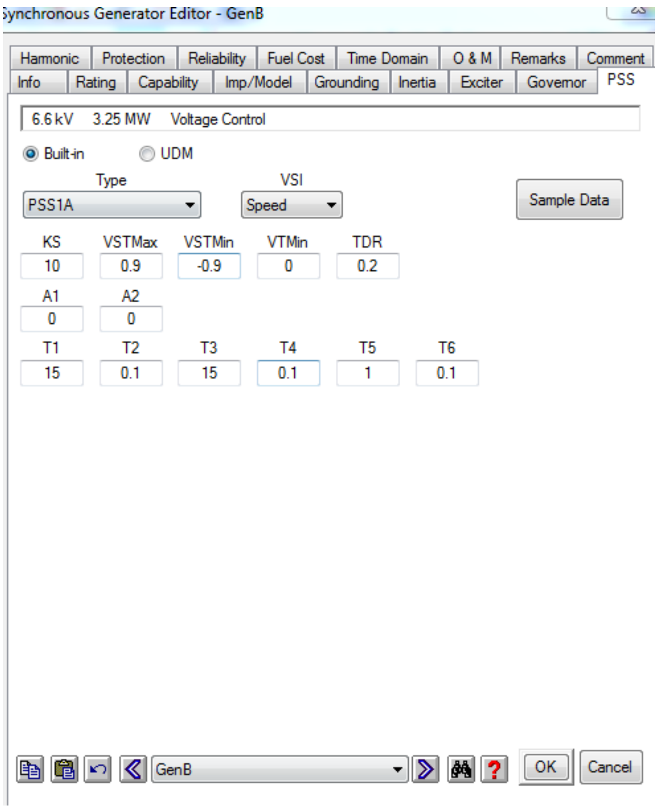
Step 11:



Step 12:



Step 13:



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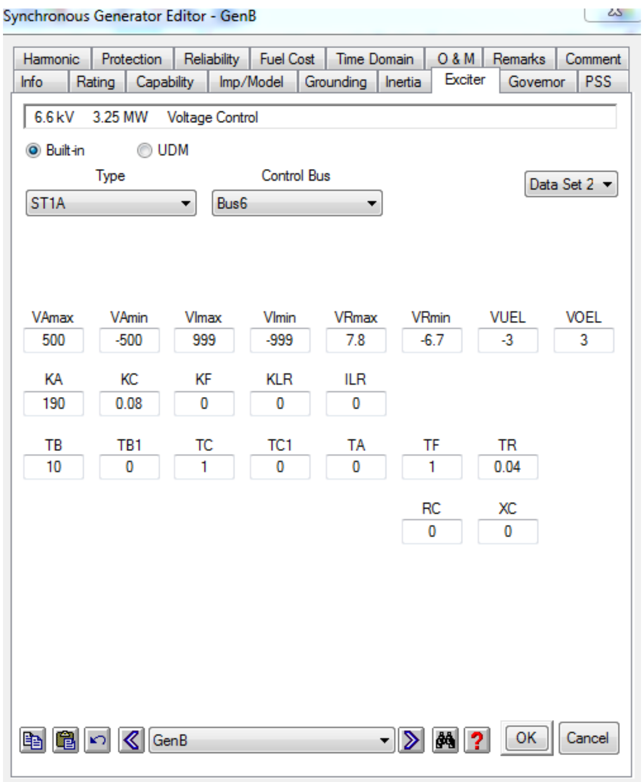

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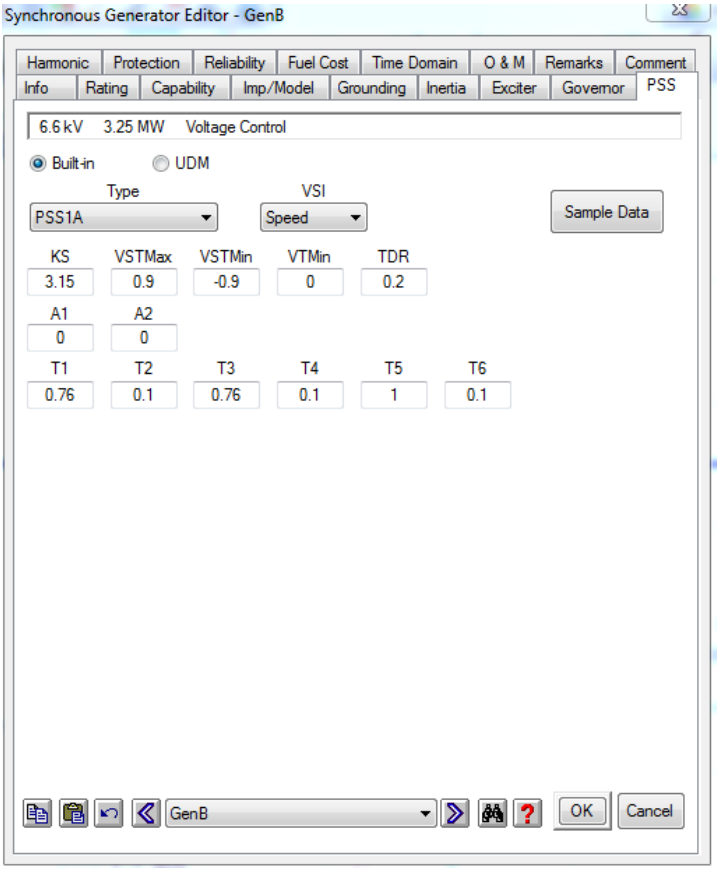
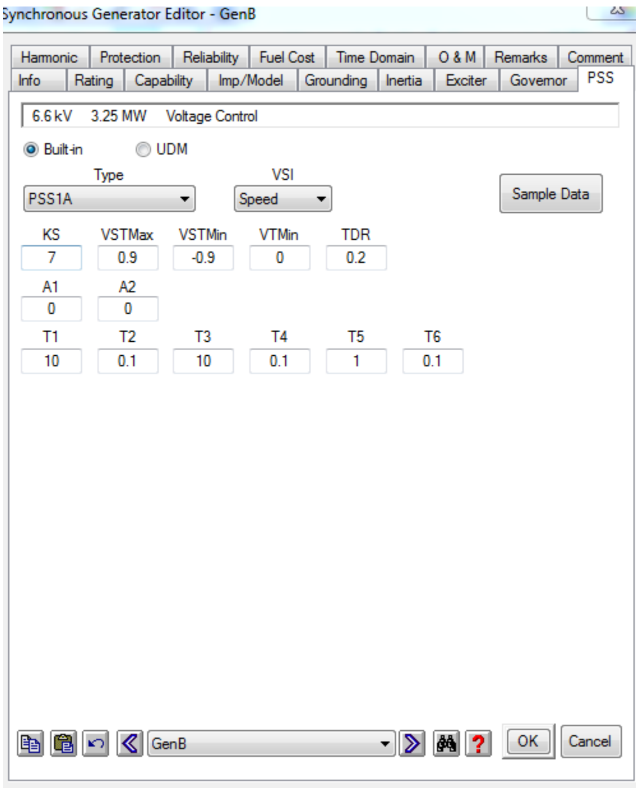
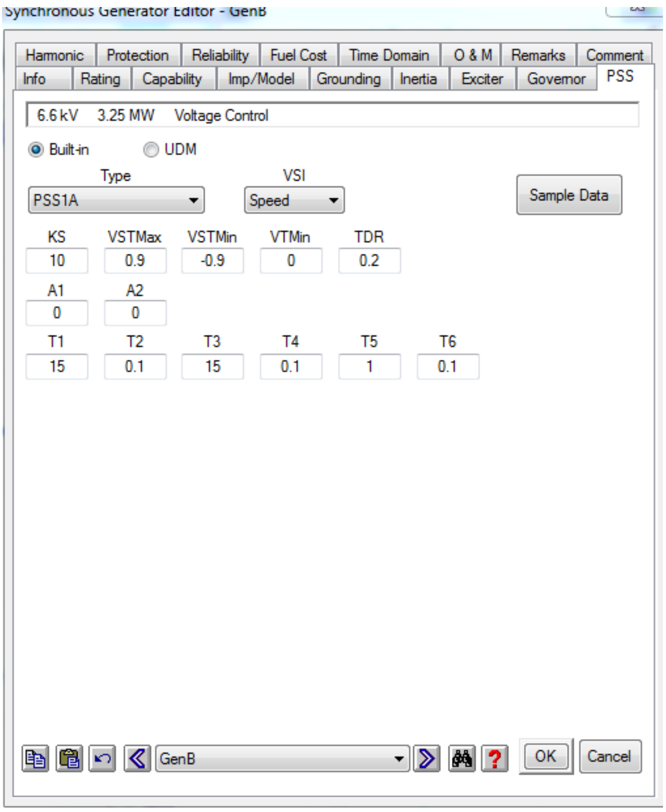


Step 16:



Step 17:



Step 18:

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.

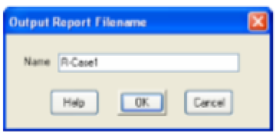


Fig. 11

Step 19:

19. When the calculation is completed, a "Transient Stability Time-Slider" dialog box will be displayed. This slider allows for animation of the result of simulation at different points in time. See Fig. 12.

   a. Click the "Toggle Action List" button to show the "Action List"
   b. Click and drag the "Slide Pointer" towards right.
   c. Notice the "Action List" is populated with the events, associated devices, and the corresponding actions in chronological order.
   d. Notice also how the One Line Diagram presentation animates while moving the "Slide Pointer".

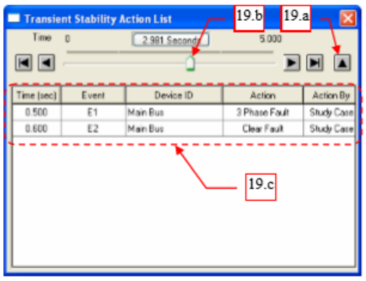


Fig. 12

Fig. 13

Step 20:

20. To view the performance of Gen1, on the "Transient Stability" toolbar, click the "Transient Stability Plots" button. See Fig. 13.

21. On the "Transient Stability Plot Selection" dialog box, do the following (See Fig. 14):
   a. On the "Device Type", select "Syn Generators"
   b. On the "Device ID", select "Gen1".
   c. There are 11 Plots available for the Syn. Generator device. But in this exercise, view only the "Power Angle (Relative)". Click the "Uncheck All" button.
   d. Check the "Power Angle (Relative)"
   e. Click "OK" button.

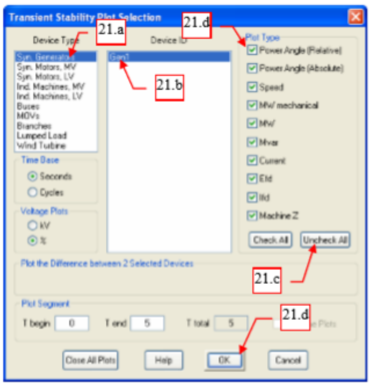


Fig. 14

3.3:TRANSIENT STABILITY CHARACTERISTICS OF SYSTEM:

Graphical output without PSS:

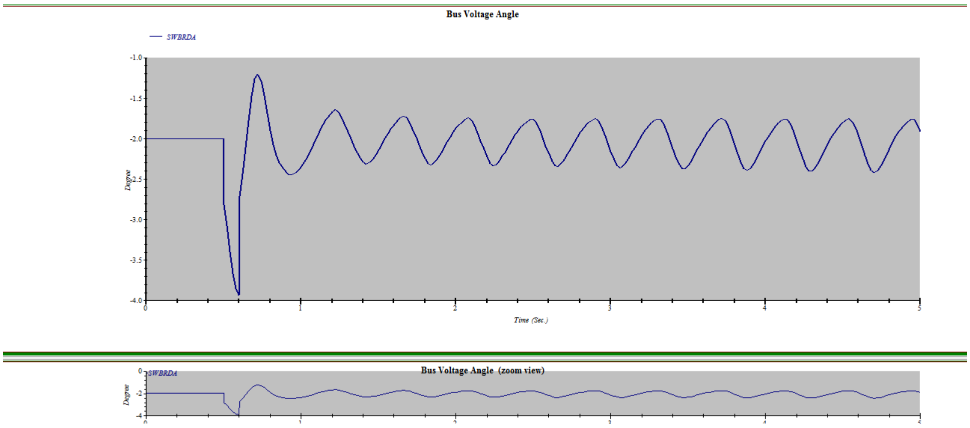


Fig 3.3.1: Bus voltage angle vs time without PSS

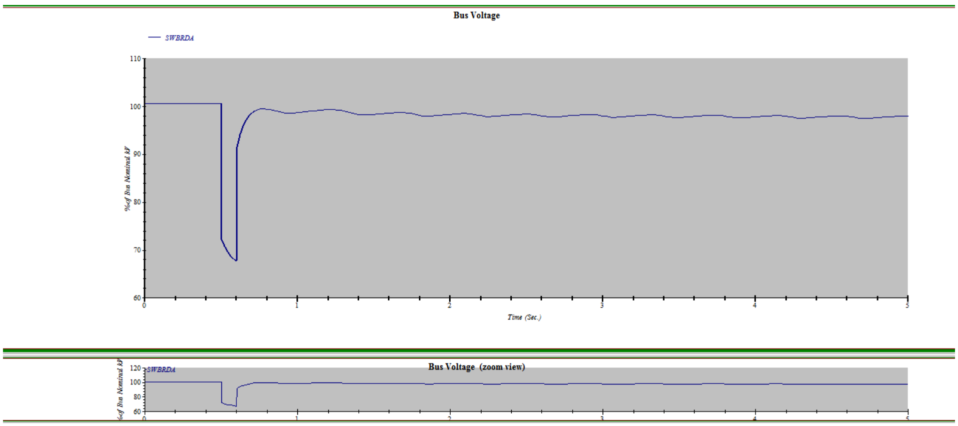


Fig 3.3.2: Bus voltage vs time without PSS

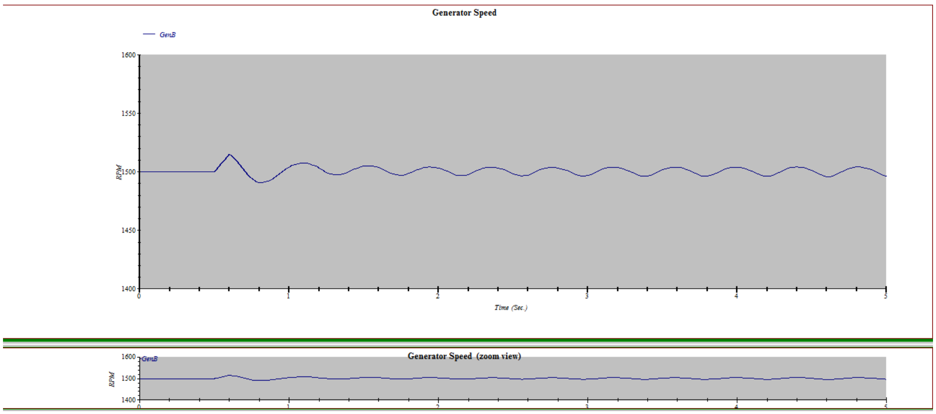


Fig 3.3.3: Generator speed vs time without PSS

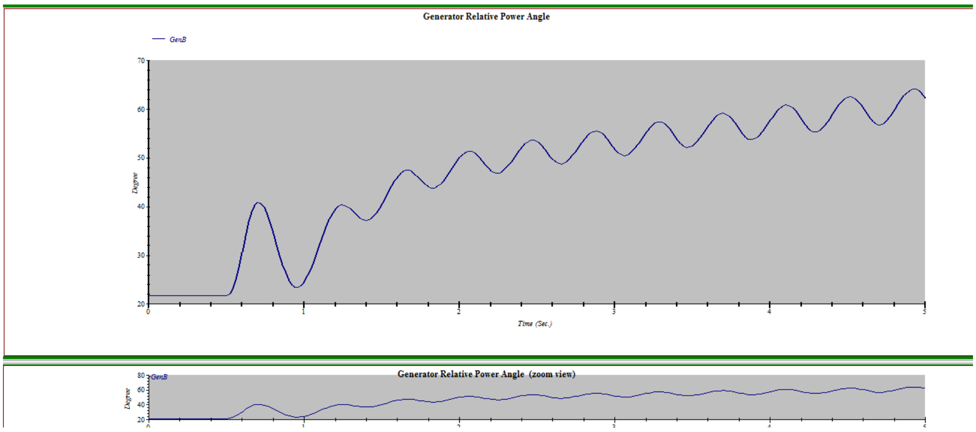


Fig 3.3.4: Generator relative power angle vs time without PSS

Graphical output applying PSS:

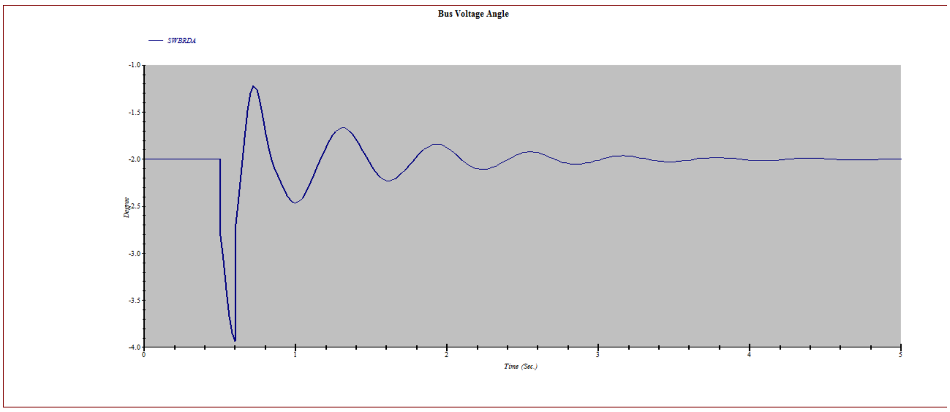


Fig 3.3.5: Bus voltage angle vs time with PSS

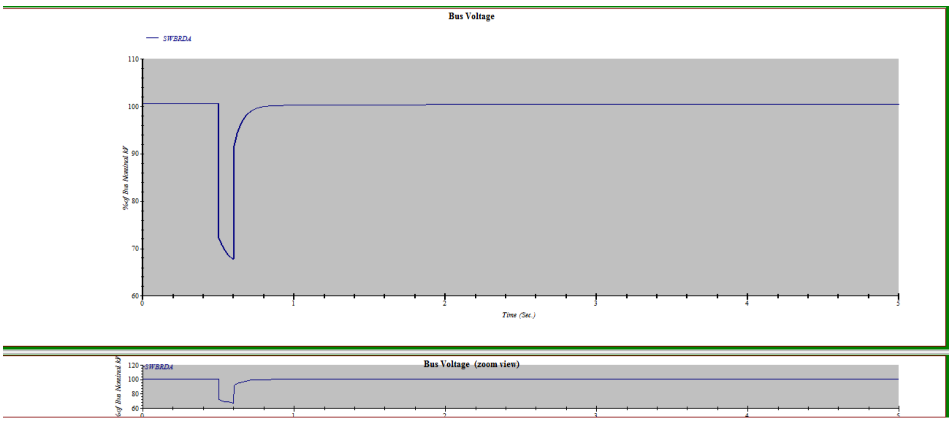


Fig 3.3.6: Bus voltage vs time with PSS

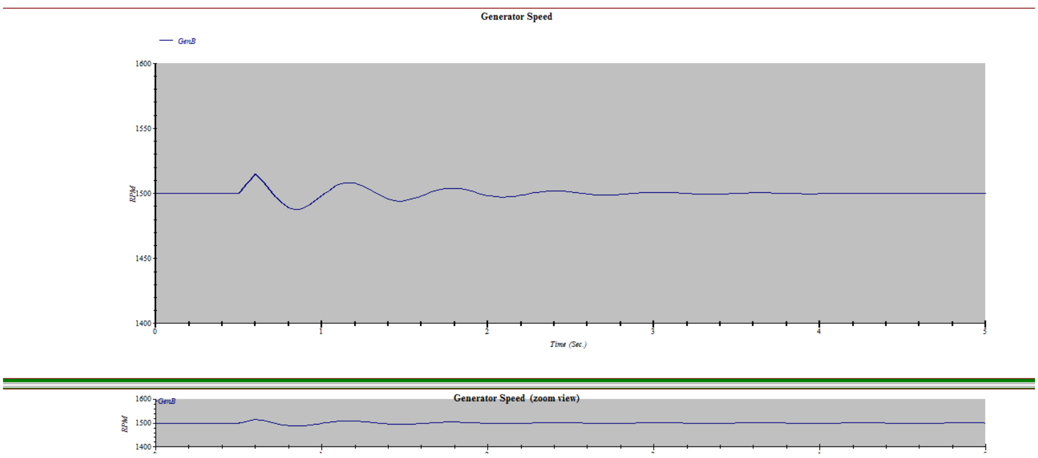


Fig 3.3.7: Generator speed vs time with PSS

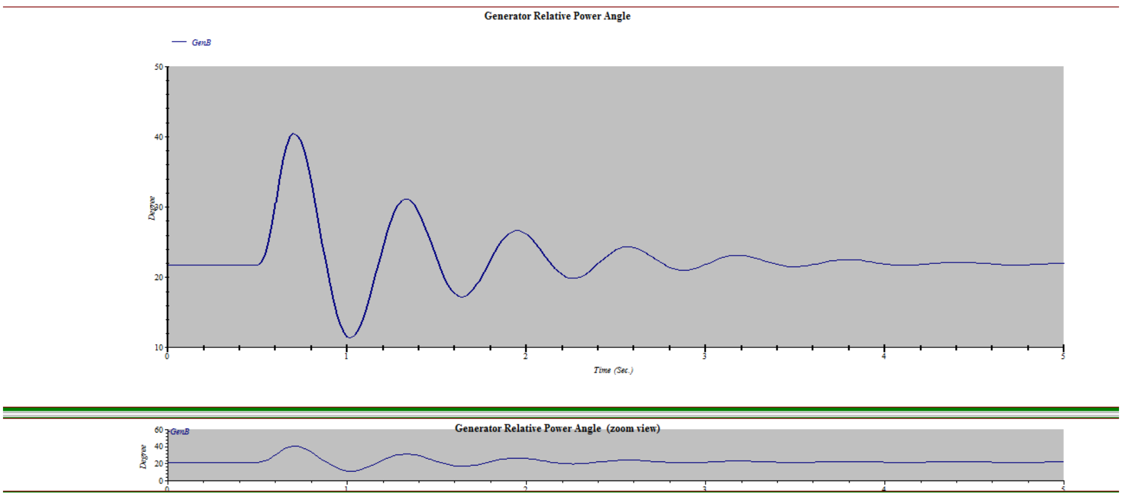


Fig 3.3.8: Generator relative power angle vs time with PSS

Parameter of Exciter gain & PSS gain:

EXCITER GAIN	POWER SYSTEM STABILITY(PSS)						PSS GAIN (KS)
	TI	T2	T3	T4	T5	T6	
SET-1	0.76	0.1	0.76	0.1	1	0.1	3.15
	10	0.1	10	0.1	1	0.1	7.0
KA=210	15	0.1	15	0.1	1	0.1	10.0
SET-2	0.76	0.1	0.76	0.1	1	0.1	3.15
	10	0.1	10	0.1	1	0.1	7.0
KA=190	15	0.1	15	0.1	1	0.1	10.0

Fig 3.3.9: Table of Exciter gain & PSS gain

4.1: CONCLUSION:

In this project the transient stability analysis has been performed on ETAP software. An ANSI.IES study system has been taken into consideration to study the transient stability characteristics of the system. Performance of the system has been investigated for typical false scenarios. A user define model of 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:

Power system stability analysis by applying PSS in ETAP the future scope is verification of the ETAP model and update the as built study as require and also verify the protection relay setting and co ordination study. Final recommendation of arc flash study to be implemented. The analysis shall consist of the following-

- **A.** Data collection
- **B.** System modeling
- **C.** Mode verification & validation
- **D.** Fault & device duty evaluation study
- **E.** Protective device coordination study
- **F.** Arc flash hazard assessment
- **G.** Project deliverables including detail report of findings & recommendation

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