International Journal of Electrical and Electronics Engineering (IJEEE)
ISSN(P): 2278-9944; ISSN(E): 2278-9952
Vol. 5, Issue 3, May 2016, 1-10


International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

# TRANSIENT STABILITY ANALYSIS OF THE IEEE 9 BUS MULTI MACHINE SYSTEM USING THE ELECTRICAL TRANSIENT ANALYZER PROGRAM (ETAP) SOFTWARE

**RAMPREET MANJHI[1] & RAMJEE PRASAD GUPTA[2]**

[1]M.Tech Student, Department of Electrical Engineering, BIT, Sindri, Dhanbad, Jharkhand, India

[2]Assistant Professor, Department of Electrical Engineering, BIT, Sindri, Dhanbad, Jharkhand, India

## ABSTRACT

It is widely accepted that transient stability is an important aspect in designing and upgrading electric power system. In this paper modeling and transient stability analysis of the IEEE 9 BUS multi machine system using the electrical Transient analyzer program (ETAP) software has been done to observe the effect of power system stabilizer (PSS) and shunt capacitor. A three phase fault has been created at Bus 7, to analyze the effect of fault and by using the PSS and shunt capacitor to the transient stability improvement has been observed. Transient stability improvement has been tested to three phase fault at bus 7 after 0.1 second and fault has been cleared after 0.3 seconds by use of PSS and shunt capacitor method for the test system the oscillation for generator electrical power has been reduced and steady state power transfer has been enhanced.

**KEYWORDS:** Transient Stability, ETAP, PSS, Shunt Capacitor

## INTRODUCTION

POWER system stability has been recognized as an important problem for secure system operation since the1920s [1][2]. Many major blackouts caused by power system instability have illustrated the importance of this phenomenon [3]. Historically, transient instability has been the dominant stability problem on most systems, and has been the focus of much of the industry's attention concerning system stability. As power systems have evolved through continuing growth in interconnections, use of new technologies and controls, and the increased operation in highly stressed conditions, different forms of system instability have emerged. For example voltage stability, frequency stability and interarea oscillations have become greater concerns than in the past. This has created a need to review the definition and classification of power system stability. A clear understanding of different types of instability and how they are interrelated is essential for the satisfactory design and operation of power systems. Classification of power system stability has been shown in figure 1.

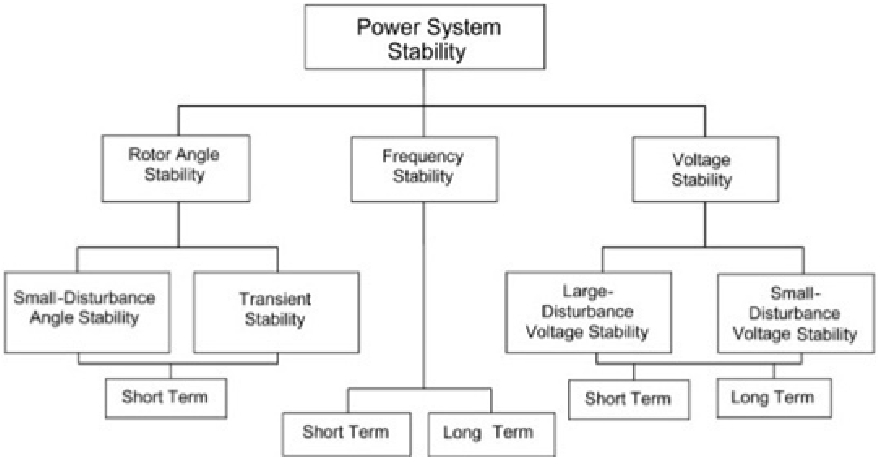


**Figure 1: Classification of Power System Stability**

The transient stability analysis is used to evaluate the ability of an electric power system to regain the state of the operating equilibrium after being subjected to a physical disturbance [4]. The stability performance of the power system depends on the type of disturbance and the initial operational condition. When a large disturbance subject to power system, the voltages will drop, and if this situation occurs for a long time, the synchronization will be lost. It may even lead to the power system blackout. Examples of large disturbances are short circuit fault, loss of loads, and loss of generations.

A fault in the system will lead to instability and the machine will fall out of synchronism. If the system can't sustain till the fault is cleared, then the whole system will be in stabilized. During the instability not only the oscillation in rotor angle around the final position goes on increasing but also the change in angular speed. In such a situation the system will never come to its final position. The unbalanced condition or transient condition may leads to instability where the machines in the power system fall out of synchronism.

The system is subjected to a large variety of disturbances. The switching on and off of an appliance in the house is also a disturbance depending upon the size and capability of the interconnected system. Large disturbances such as lightning strokes, loss of transmission line carrying bulk power do occur in the system. Therefore transient stability is defined as the ability of the power system to survive the transition following the large disturbance and to reach an acceptable operating condition.

The physical phenomenon that occurs during a large disturbance is that there will be an imbalance between the mechanical power input and the electrical power output. This will tend to run the generator at high speed. The result will be the loss of synchronism of the generator and the machine will be disconnected from the system. This phenomenon is referred to as a generator going out of step. The Etap Transient Stability Analysis is designed to investigate the system dynamic response disturbance. The program models dynamic characteristics of a power system, implements the user-defined events and action, solves the system network equation and machine differential equation interactively to find out system and machine response in time domain

**Power System Stabilizer**

The basic of a power system stabilizer (PSS) is to add damping to the generator oscillation by using auxiliary stabilizing signal(s). To provide damping, the stabilizer must produce a component of electrical torque in phase with the rotor speed variation. This is achieved by modulating the generator excitation so as to develop a component of electrical torque in phase with rotor speed deviation. Shaft speed, integral of power and terminal frequency are among the commonly used input signals to PSS.[5]. PSS based on shaft speed signal has been use successfully since the mid-1960s.a technique developed to derive a stabilizing signal from measurement of shaft speed of a system. Among the important consideration in the design of equipment for the measurement of speed deviation is the minimization of noise caused by shaft run out and other causes.[5-6] the allowable level of noise is dependent on its frequency. For noise frequency below 5Hz, the level must be less than 0.02%, since significant changes in terminal voltage can be produced by low-frequency changes in the field voltage. The application of shaft speed stabilizer to thermal unit requires a careful consideration of the effects on torsional oscillation. The stabilizer, while damping the rotor oscillation, can cause instability of the torsional modes. One approach successfully used to circumvent the problem is to sense the speed at a location on the shaft near the nodes of the critical torsional modes [7-8]. In addition, an electronic filter is used in stabilizing path to attenuate the torsional components. Power system stabilizer which has been used is as shown in figure 2.

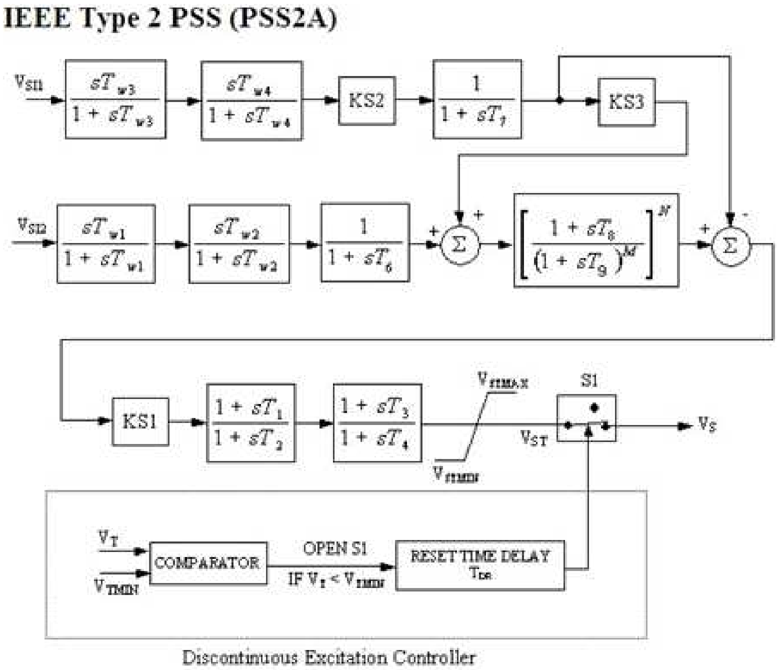


**Figure 2: Ieee Type 2 (Pss2a)**

**Shunt Capacitors**

Shunt capacitor supply reactive power and boost local volatages. They are used throughout the system and applied in wide range of sizes

Shunt capacitors were first used in mid-1910s for power factor correcation. The early capicators employed oil as the dielectic. Because of their large size and weight, and high cost, their use at time limted. In the 1930s, the introducation of chepar dilectric material and othe other improvement in construcation brought about singificant reducation in price and size the use of shunt capacitors incresed phenomenally since 1930s. The principal advantage of shunt capacitor are their low cost and their flexibility of installation and operation. They are readily applied at various points in the system, thereby contributing to effciency of power transmission and distribuation.

Shunt capacitor are used to compensate for the reactive power $XI^2$ losses in system and to ensure satisfactory voltage levels during heavy loading conditions.capacitor banks of approprite size are conncted either directly to the high voltage bus. They are normallay distributed throught the transmission system so as to minimze losses and volatage drops.

**Iee 9 Bus Tested System**

The system has been considered here in 9 bus multi-manchine system as shown below Figure 3.

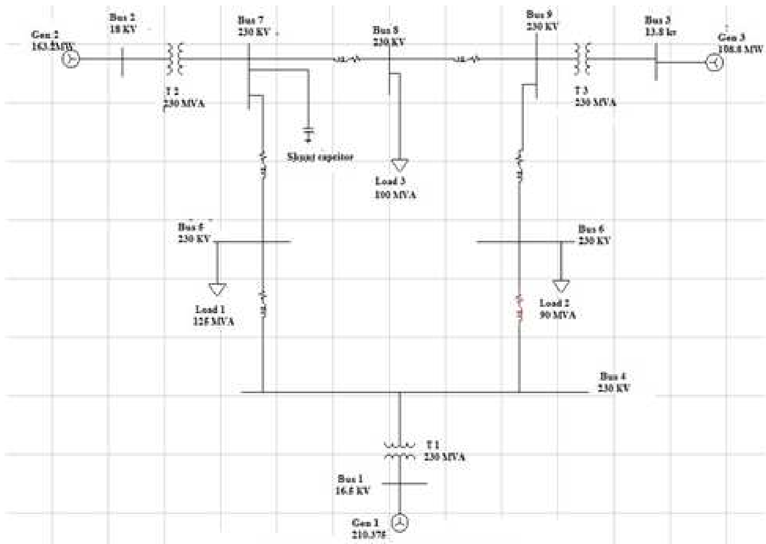


**Figure 3: 9 Bus Multi-Machine System**

9 Bus Multi-machine consisted three generators,six transmission line,three transformerand three static loads are respectively 125MVA,100MVA and 90MVA. Another is Gen 1, Gen 2, Gen 3 rated are respectively 210.375MW, 163.3MW, 108.8MW. All other parameter of generators are shown below in table 1,2,3

**Table 1: Synchronous Machine Parameters**

| Machine | | | Rating | | | Positive Sequence Impedance (%) | | | | | | | Zero Seq. Z(%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Type | Model | MVA | KVA | Ra | Xd” | Xd’ | Xd | Xq” | Xq’ | Xq | X1 | X/R | R0 | X0 |
| Gen 1 | Generator | Subtransient, Round-Rotor | 247.500 | 16.500 | 1.00 | 19 | 28 | 155 | 19 | 65 | 155 | 15 | 7 | 1 | 7 |
| Gen 2 | Generator | Subtransient, Round-Rotor | 192.000 | 18.000 | 1.00 | 19 | 28 | 155 | 19 | 65 | 155 | 15 | 7 | 1 | 7 |
| Gen 3 | Generator | Subtransient Round-Rotor | 128.000 | 13.800 | 1.00 | 19 | 28 | 155 | 19 | 65 | 155 | 15 | 7 | 1 | 7 |

**Table 2: Dynamics Parameter of Synchronous Machine**

| Machine | Connected Bus | Time Constant(Sec.) | | | | H (Sec.), D(Mwpu/Hz) & Saturation | | | | | Grounding | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Id | Id | Tdo” | Tdo’ | Tqo” | Tqo’ | H | %D | S100 | S120 | Sbreak | Conn | Type |
| Gen 1 | Bus 1 | 0.035 | 6.500 | 0.035 | 1.250 | 70.920 | 0 | 1.070 | 1.180 | 0.800 | Wye | Solid |
| Gen 2 | Bus 2 | 0.035 | 6.500 | 0.035 | 1.250 | 19.200 | 0 | 1.070 | 1.180 | 0.800 | Wye | Solid |
| Gen 3 | Bus 3 | 0.035 | 6.500 | 0.035 | 1.250 | 9.030 | 0 | 1.070 | 1.180 | 0.800 | Wye | Solid |

**Table 3: Mechanical Parameter of Synchronous Machine**

| Machine | | Generator | | | Coupling | | | Prime Mover | | | Equivalent Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Id | Type | Rpm | $WR^2$ | H | Rpm | $WR^2$ | H | Rpm | $WR^2$ | H | Rpm | $WR^2$ | H |
| Gen 1 | Gen | 1800 | 7817461 | 23.640 | 1800 | 7817461 | 23.640 | 1800 | 7817461 | 23.640 | 1800 | 23452382 | 70.920 |
| Gen 2 | Gen | 1800 | 410453.97 | 6.40 | 1800 | 410453.97 | 6.400 | 1800 | 410453.97 | 6.400 | 1800 | 4925446.5 | 19.200 |
| Gen 3 | Gen | 1800 | 514776.97 | 3.010 | 1800 | 514777.41 | 3.010 | 1800 | 514776.97 | 3.010 | 1800 | 1544331.38 | 9.030 |

**Table 4: Power System Stabilize (PSS) Input Data Type: Pss2a**

| Generator ID | VS11 | VS12 | KS1 | KS2 | KS3 | VST Max | VST Min | VT Min | TDR | Tw1 | Tw2 | Tw3 | Tw4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | N | M | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | |
| Gen 1 | Elec. Power | Speed | 20 | 0.001 | 1 | 0.200 | -0.066 | 0.000 | 0.200 | 10.000 | 10.000 | 10.00 | 10.00 |
| | | | 4 | 2 | 0.160 | 0.020 | 0.160 | 0.020 | 0.000 | 0.000 | 0.300 | 0.150 | |
| Gen 2 | Elec. Power | Speed | 20 | 0.001 | 1 | 0.200 | -0.066 | 0.000 | 0.200 | 10.000 | 10.000 | 10.00 | 10.00 |
| | | | 4 | 2.000 | 0.160 | 0.020 | 0.160 | 0.020 | 0.000 | 0.000 | 0.300 | 0.150 | |
| Gen 3 | Elec. Power | Speed | 20 | 0.001 | 1 | 0.200 | -0.066 | 0.000 | 0.200 | 10.000 | 10.000 | 10.00 | 10.00 |
| | | | 4 | 2.000 | 0.160 | 0.020 | 0.160 | 0.020 | 0.000 | 0.000 | 0.000 | 0.300 | 0.150 |

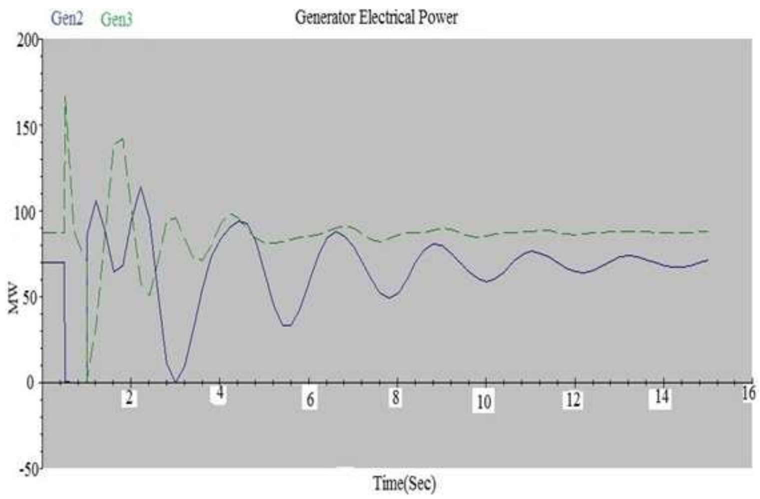


**Figure 4: Generator Electrical Power without PSS and Shunt Capacitor**

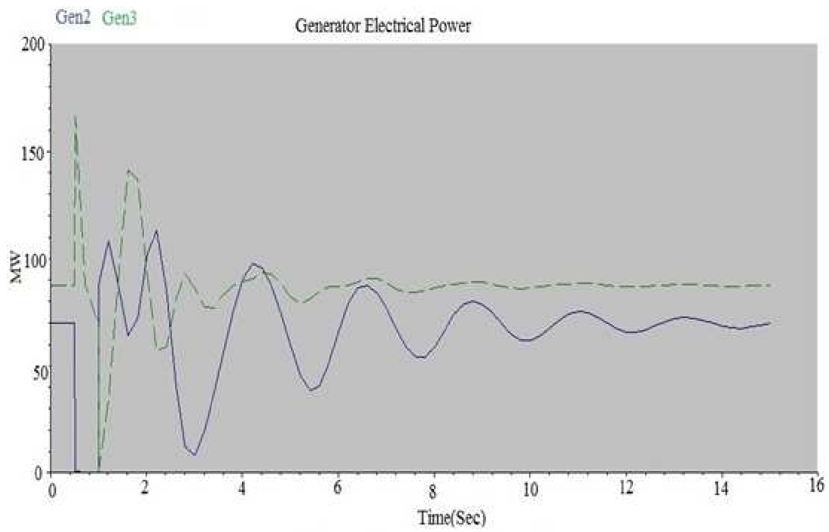


**Figure 5: Generator Electrical Power with Pss and Shunt Capacitor**

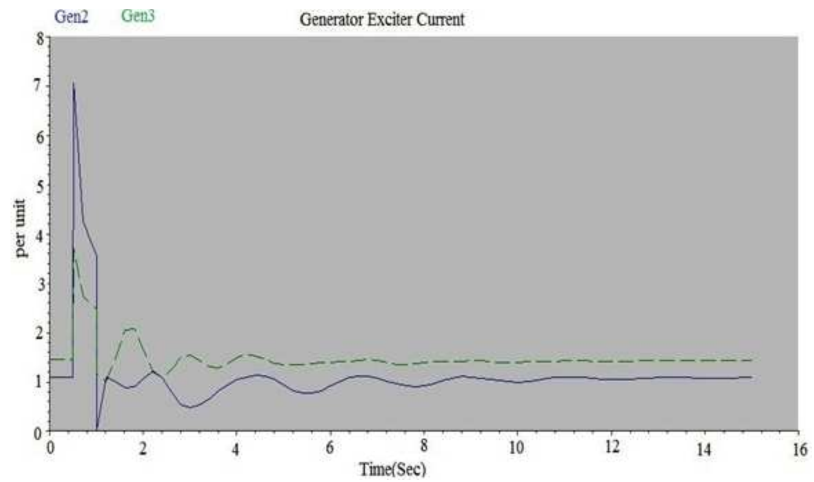


**Figure 6: Generator Exciter Current without PSS and Shunt Capacitor**

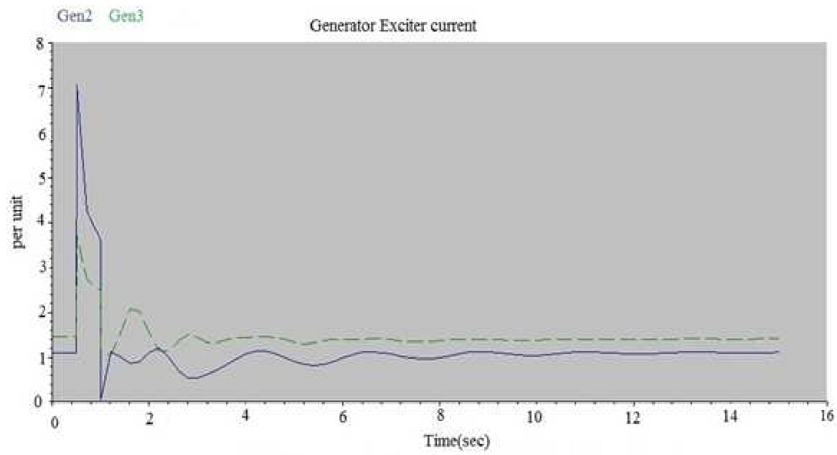


**Figure 7: Generator Exciter Current with PSS and Shunt Capacitor**

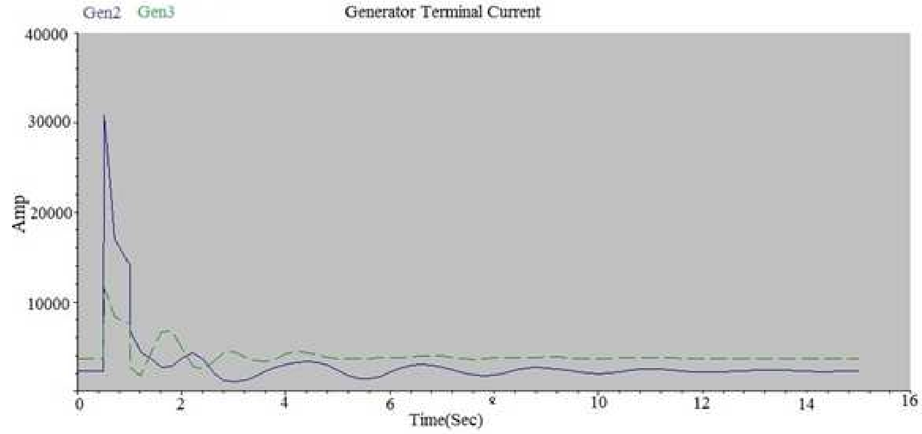


**Figure 8: Generator Terminal Current without PSS and Shunt Capacitor**

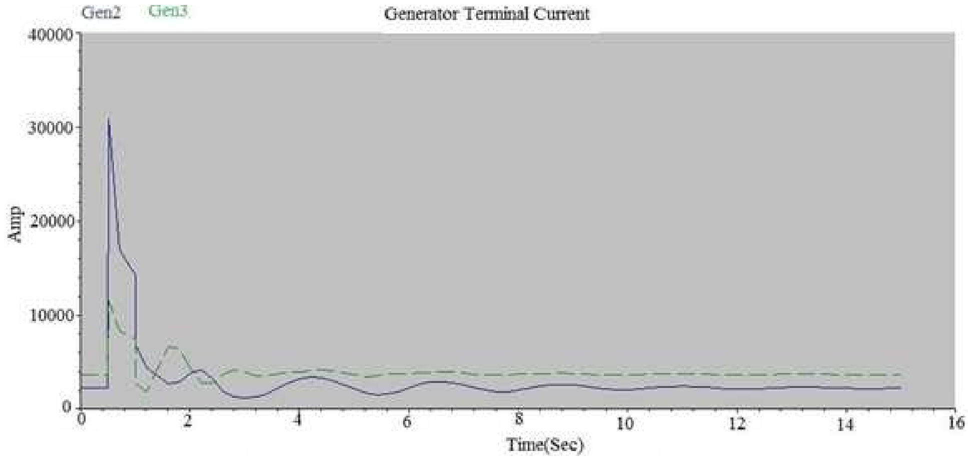


**Figure 9: Generator Terminal Current with PSS and Shunt Capacitor**

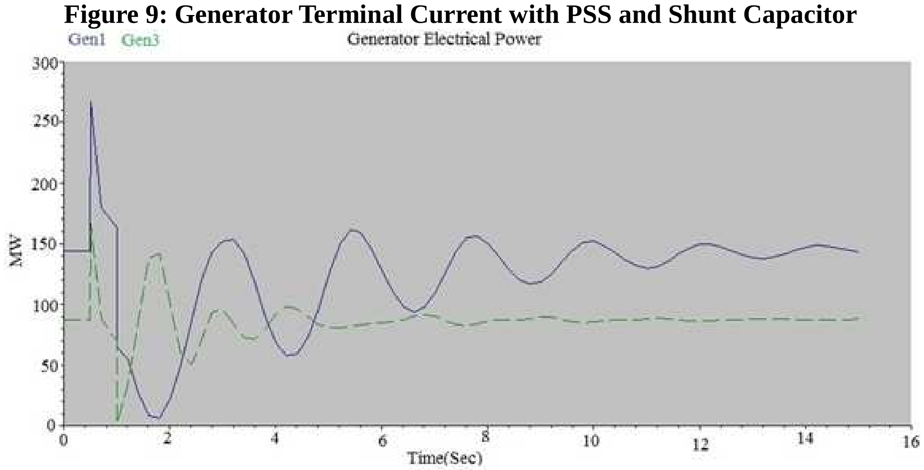


**Figure 10: Generator Electrical Power without PSS and Shunt Capacitor**

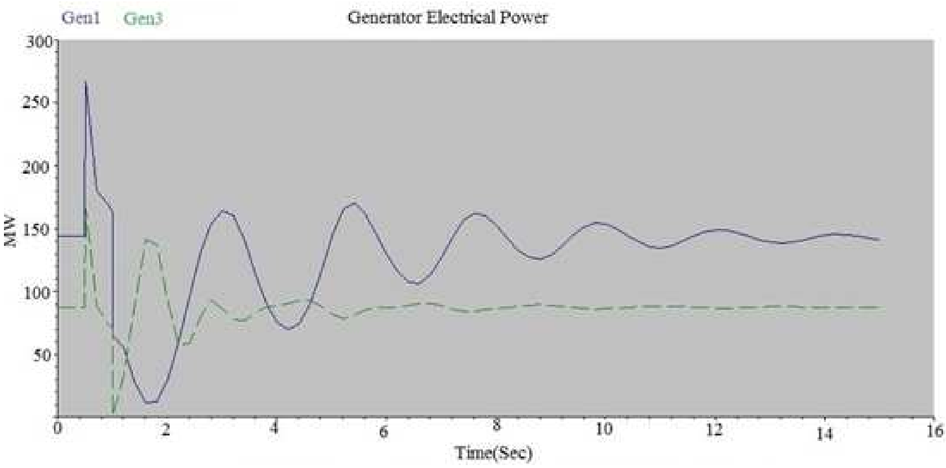


**Figure 11: Generator Electrical Power with PSS and Shunt Capacitor**

## RESULTS AND DISCUSSIONS

The generator electrical power disturbance as shown in figure 4 for Gen 3 is upto10 sec and after that it achieves its steady state and disturbance for Gen 2 is upto 14 sec then after that it attains its steady state without using PSS and shunt capacitor. But as shown in figure 5 Gen 3 gets its steady state is within 8 sec and Gen 2 attains steady state within 12 sec using PSS and shunt capacitor. The generator exciter current disturbance has been shown in figure 6. Gen 2 exciter current remains fluctuating upto 10 sec without using PSS and shunt capacitor as shown in figure 7. But, the Gen 2 exciter current gets its steady state using PSS and shunt capacitor in 8 sec. As shown in figure 8 generator terminal current Gen 2 is fluctuating upto 10 sec and for Gen 3 is upto 4 sec after using PSS and shunt capacitor as shown in figure 9

## CONCLUSIONS

In this paper modeling and transient stability analysis of the IEEE 9 BUS multimachine system using the electrical Transient analyzer program (ETAP) software has been done to observe the effect of power system stabilizer (PSS) and shunt capacitor. Transient stability improvement has been tested to three phase fault at different point with and without coordinated effect of PSS and shunt capacitor. IEEE type 2 PSS has been used from the library of ETAP.

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