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Stability Improvement of Multi-Machine Power System Network using STATCOM & UPFC

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Abstract: Recent power system transmission networks are becoming with increasing complexity due to growing demand and restrictions on building new lines. Loss of stability is one of the major problem of such a modern power system following a disturbance. Transient stability control is an important concept which ensuring the stable operation of power system during the fault and large disturbances. FACTS technologies are raise to be very effective in a power system transmission network for better controllability and increase power transfer capability without sacrificing the desired stability margin. This paper provides the comparative performance of STSTCOM, SVC and UPFC for improvement of transient stability of IEEE 9 bus power system. Static Synchronous Compensator and Static Var Compensator are the shunt devices of the Flexible AC Transmission Systems (FACTS) family.

When the system voltage is low, STATCOM generates reactive power and when the system voltage is high then it absorbs reactive power whereas SVC is also operates as same as the STATCOM. SVC provides the fast acting dynamic compensation in case of severe fault. The UPFC is more effective Flexible AC Transmission Systems (FACTS) device for controlling active and reactive power flow in a transmission line and power oscillation damping by controlling its series and shunt parameters. To analyzing the effects of STATCOM, UPFC and SVC on transient stability performance of the system by using the MATLAB/Simulink environment for multi- machine system. The performance of STATCOM, SVC and UPFC are compared with each other.

The simulation results will show the effective and robustness of all the three FACTS devices. Higher degree Flexible AC Transmission Systems (FACTS) device can be identified by this project for transient stability of IEEE 9 bus power system.

Keywords: FACTS, STATCOM, SVC and UPFC, Transient Stability and IEEE 9 bus power system.

I. INTRODUCTION

Power system generally consist of three stages: such as generation, transmission, and distribution. The First stage is generation, the electric power is generated generally by using synchronous generators. Then the voltage range is increased by transformers before the power is transmitted in order to decrease the line currents which consequently reduce the power transmission losses. After the transmission, the voltage is stepped down using transformers in order to be distributed accordingly. Power systems are planned to provide uninterrupted power supply that hold voltage stability.

However, due to undesired events, such as lightning, accidents or any other uncertain events, short circuits between the phase conductors of the transmission lines or between a phase conductor and the ground which may occur is called a fault. Due to occurring of a fault, one or more generators may be severely disturbed causing an instability between generation and demand. If the fault persists and is not cleared in a pre-specified time frame, it may cause strong damages to the equipment's which in turn may lead to a power loss and power outage.

Hence, antifouling equipment's are compartment to observe faults and clear/separate faulted parts of the power system as quickly as possible in front the fault energy is pass on to the rest of the system.

MATLAB Simulink is an interactional environment for modelling and simulating a wide variety of dynamic systems. A system is built easily using blocks and results can be displayed quickly. Simulink is used for perusing the effects of non-linearity of the system and thus is an ideal research tool.

Use of Simulink is growing rapidly for research work in the area of power system and also in the other areas. Time domain simulation method is implemented in this paper. In this paper multi machine nine bus system is modelled in Matlab/simulink and transient stability analysis is done with the fault located in a bus.

II. POWER SYSTEM STABILITY

Electrical Power system stability is the ability of an electric power system, for a given initial operating condition, to retrieve a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact. Stability phenomenon is a single problem associated with various forms of instabilities affected on power system due to the high dimensionality and complexity of power system constructions and behaviors. For properly understood of stability, the classification is essential for significant power system stability analysis. Stability classified based on the nature of resulting system instability (voltage instability, frequency instability), the size of the disturbance (small disturbance, large disturbance) and time frame of stability (short term, long term). In the other hand, stability broadly classified as steady state stability and dynamic stability. Steady state stability is the ability of the system to transit from one operating point to another under the condition of small load changes. Power system dynamic stability appears in the literature as a class of rotor angle stability to describe whether the system can maintain the stable operation after various disturbances or not.

A. Transient Stability

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

III. FACTS CONTROLLERS

FACTS are defined by the IEEE as “a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability”. Basically, FACTS controllers can be divided into four categories:

1) Series Controller
2) Shunt Controller
3) Combined series-series Controller
4) Combined series-shunt Controller

Table 1. Comparison among FACTS Controllers

Name	Type	Controller Used	Purpose
SVC	Shunt	Thyristor	Voltage Control
SSSC	Series	GTO	Power Flow Control
STATCOM	Shunt	GTO	Voltage Control
UPFC	Shunt and Series	GTO	Voltage and Power Flow Control
TCSC	Series	Thyristor	Power Flow Control
TCPAR	Shunt and Series	Thyristor	Power Flow Control

A. Static VAR Compensator (SVC)

Static VAR Compensator (SVC) provides the fast reactive power on high voltage transmission networks. An SVC is based on thyristor controlled reactors (TCR), thyristor switched capacitors (TSC), and/or Fixed Capacitors (FC) tuned to Filters as shown in fig1. A TCR consists of a fixed reactor in series with a bi-directional thyristor valve. TCR reactors are as a rule of air core type, glass fibre insulated, epoxy resin impregnated.

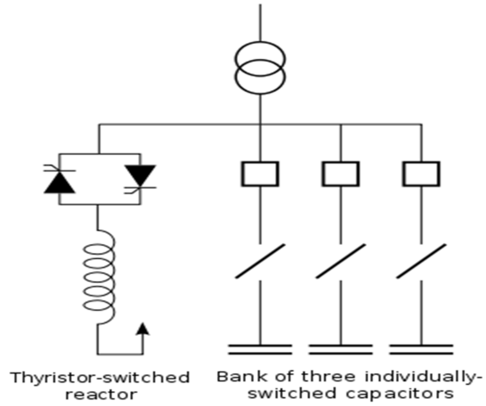

Figure 1. SVC Model

Static VAR Compensator (SVC) had a great advantage over simple mechanically-switched compensation schemes is their fast instantaneous response to changes in the system voltage. For this reason they are often operated at close to their zero-point in order to maximize the reactive power correction they can rapidly provide in system whenever required. They are in general cheaper, higher- capacity, faster, efficient and more reliable over dynamic compensation schemes such as synchronous condensers.

B. Static Synchronous Compensator (STATCOM)

STATCOM is a shunt-connected static Var compensator whose capacitive or inductive output current can be controlled independently of the ac system voltage. STATCOM is made up of a coupling transformer, a VSC and a dc energy storage device as shown in fig2. STATCOM is capable of exchanging reactive power with the transmission line

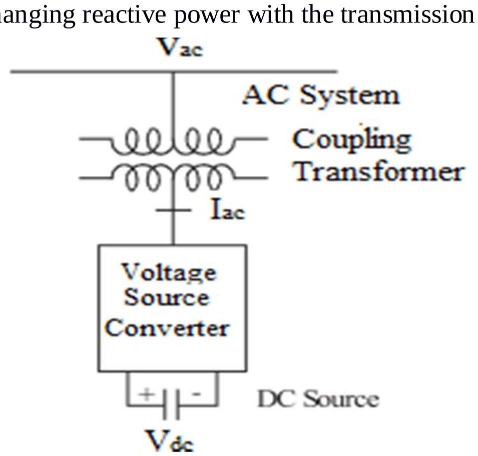

Figure 2. STATCOM Model

C. Unified Power Flow Controller (UPFC)

The *Unified Power Flow Controller (UPFC)* is the most versatile FACTS controller developed so far, with all-encompassing capabilities of voltage regulation, series compensation, and phase shifting. It can independently and very rapidly control both real- and reactive power flows in a transmission line. It is configured as shown in Fig.3 and comprises two VSCs coupled through common dc terminal. One VSC—converter1—is connected in shunt with the line through a coupling transformer; the other VSC—converter 2— is inserted in series with the transmission line through an interface transformer. The dc voltage for both converters is provided by a common capacitor bank. The series converter is controlled to inject a voltage phasor, Vpq, in series with the line, which can be varied from 0 to Vpq max. Moreover, the phase angle of Vpq can be independently varied from 00 to 3600. In this process, the series converter exchanges both real and reactive power with the transmission line. Although the reactive power is internally generated/ absorbed by the series converter, the real-power generation/ absorption is made feasible by the dc-energy–storage device—that is, the capacitor. The shunt-connected converter 1 is used mainly to supply the real-power demand of converter 2, which it derives from the transmission line itself. The shunt converter maintains constant voltage of the dc bus.

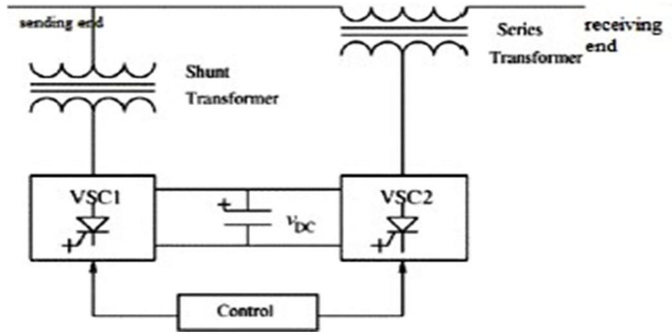

Figure 3. UPFC Model

D. Power System Stabilizers

PSS have been extensively used as supplementary excitation controllers to damp out the low frequency oscillations and enhance the overall system stability. Fixed structure stabilizers have practical applications and generally provide acceptable dynamic performance. There have been arguments that these controllers, being tuned for one nominal operating condition, provide sub optimal performance when there are variations in the system load. There are two main approaches to stabilize a power system over a wide range of operating

Conditions, namely robust control. The block diagram for the designed conventional PSS is shown in Fig.4

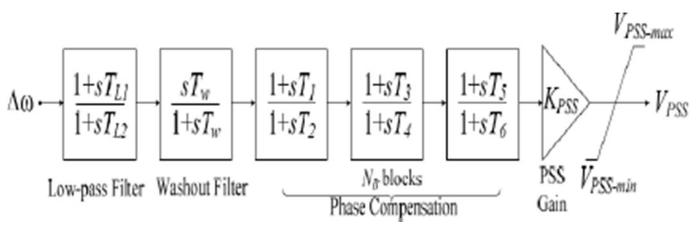

Figure 4. Power System Stabilizer Model

IV. SIMULATION MODEL AND RESULTS

A. IEEE 9-bus power system installed with P

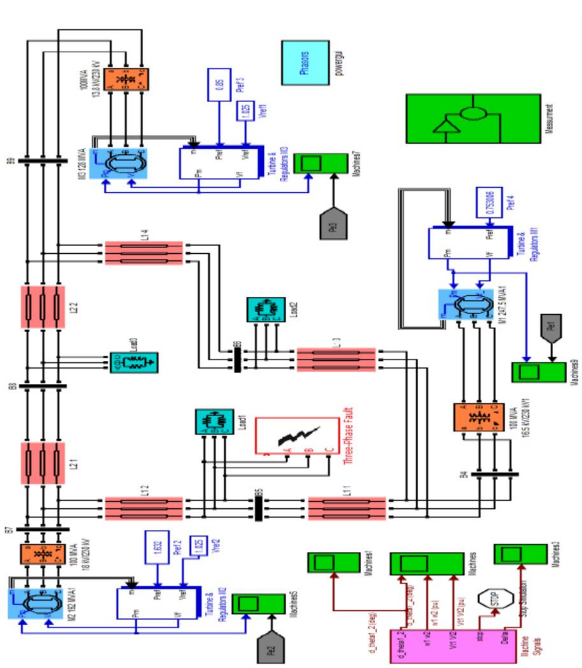

Figure 5. Simulink model of three machine 9-busbar power system network with PSS

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Table 2. Stability chart for PSS

Fault position	PSS position	Stability time for delta1_2 (in sec)	Stability time for delta2_3 (in sec)	Stability time for delta3_1 (in sec)
Between bus 5 and bus 7	Connected with all three machine	3.9	3.65	4.3

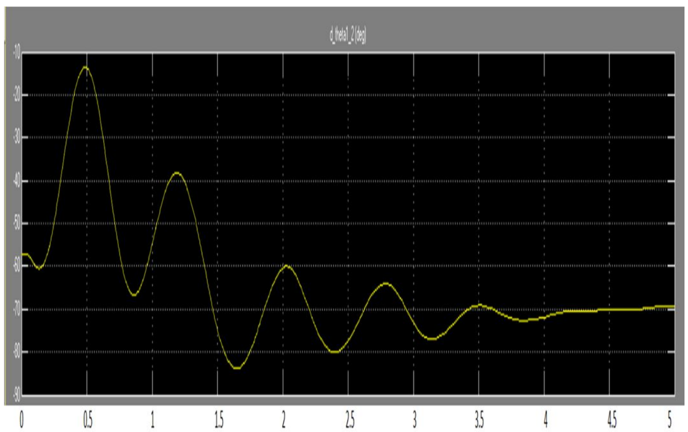
Figure 5.1Rotor angle deviation between machine M1 and M2

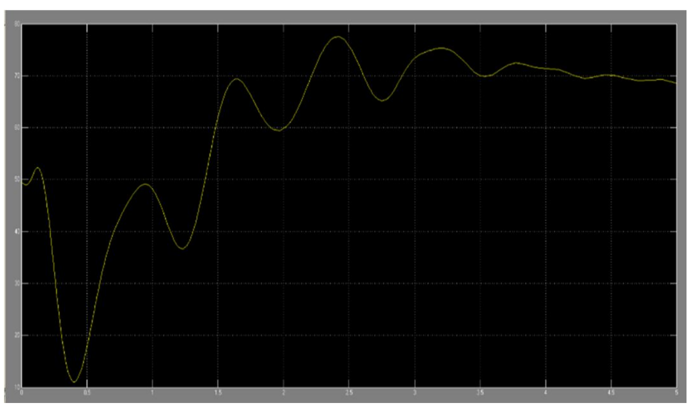
Figure 5.2. Rotor angle deviation between machine M2 and M3

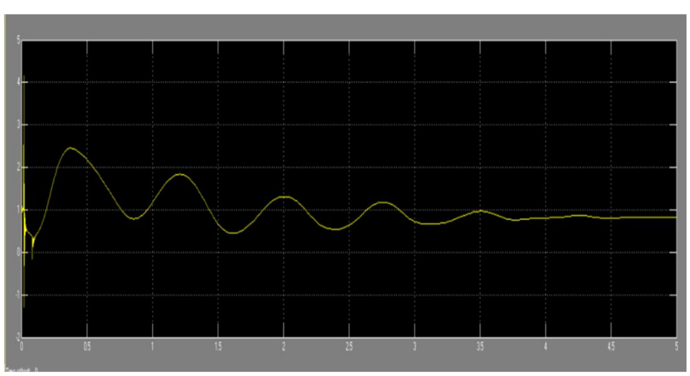
Figure 5.3. Rotor angle deviation between machine M3 and M1

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B. IEEE 9-bus power system installed with STATCOM and PSS

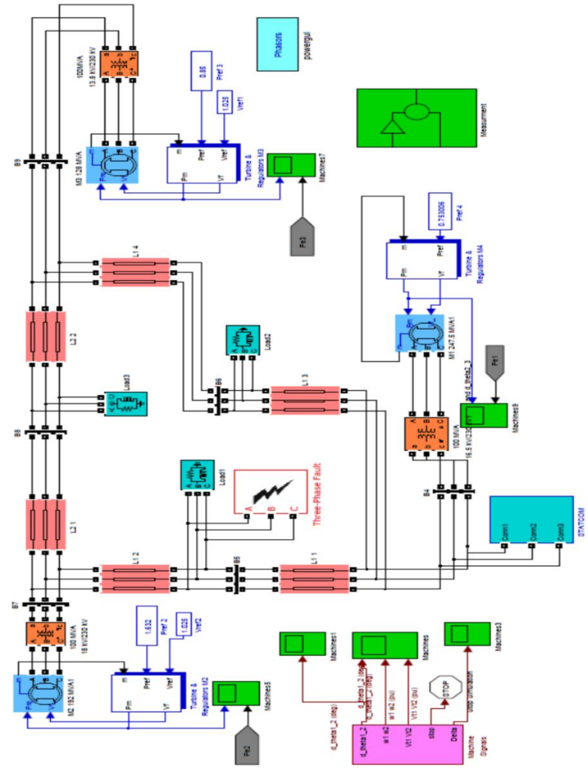

Figure 6. Simulink model of three machine 9-busbar network with PSS and STATCOM

Table 3. Stability chart for STATCOM

Fault position	STATCOM position	Stability time for delta1_2 (in sec)	Stability time for delta2_3 (in sec)	Stability time for delta3_1 (in sec)
Between bus 5 and bus 7	Between bus 4 and bus 5	4.2	4.1	4.3

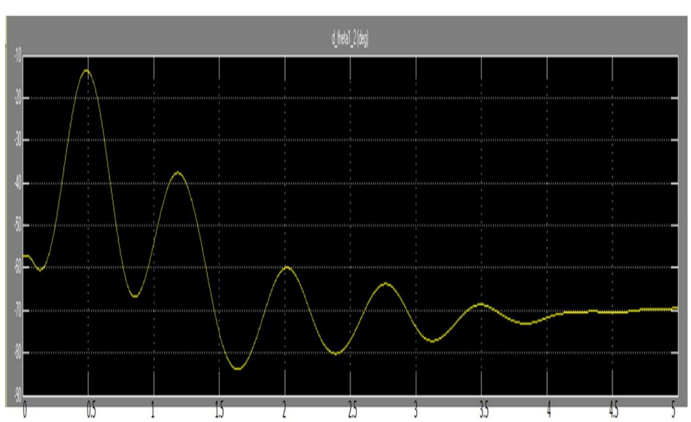

Figure 6.1. Rotor angle deviation between machine M1 and M2

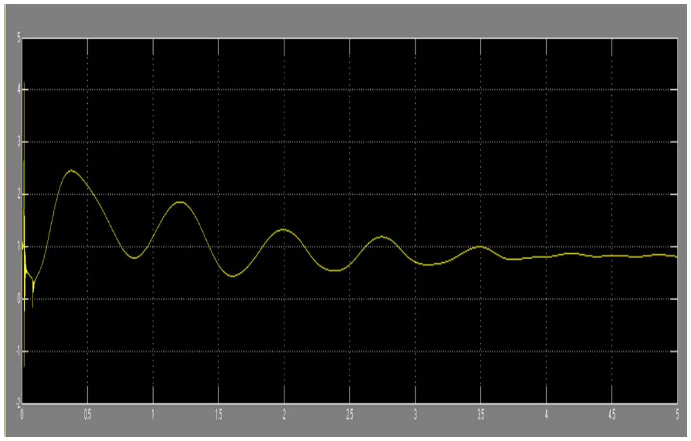

Figure 6.2. Rotor angle deviation between machine M2 and M1

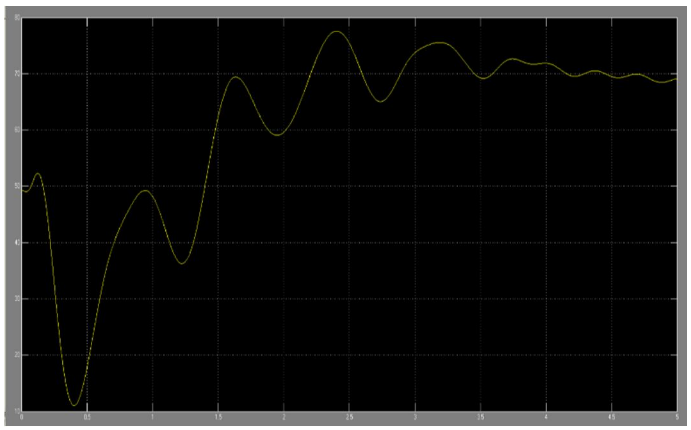

Figure 6.3. Rotor angle deviation between machine M3 and M1

C. IEEE 9-bus Power System Installed with UPFC and PSS

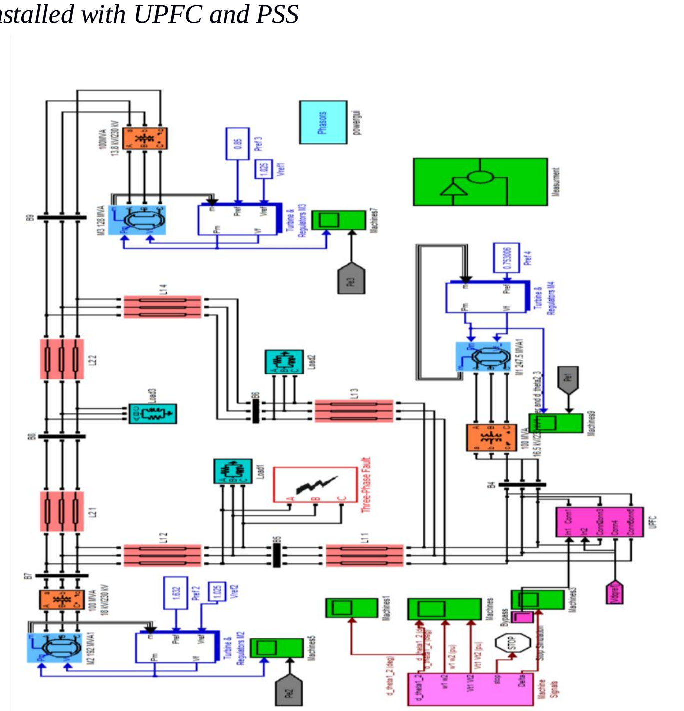

Figure 7. Simulink model of three machine 9-busbar network with PSS and UPFC

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Table 4. Stability chart for UPFC

Fault position	UPFC position	Stability time for delta1_2 (in sec)	Stability time for delta2_3 (in sec)	Stability time for delta3_1 (in sec)
Between bus 5 and bus 7	Between bus 4 and bus 5	3.7	3.42	3.8

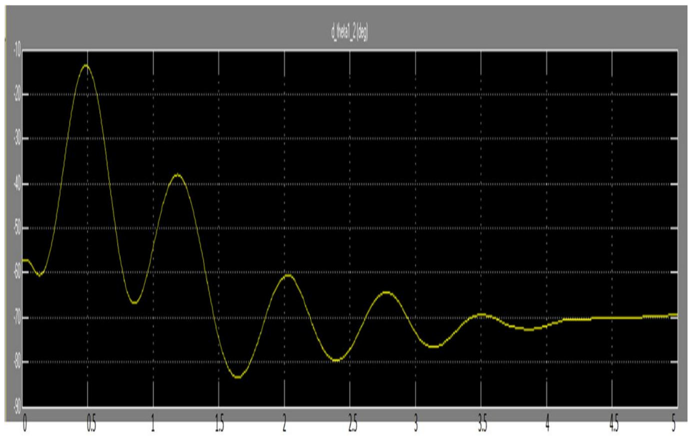

Figure 7.1. Rotor angle deviation between machine M1 and M2

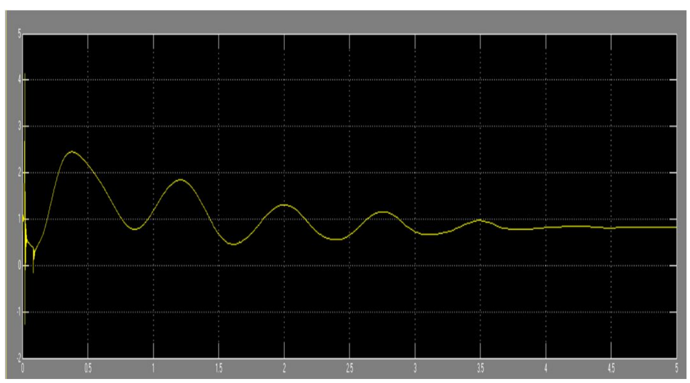

Figure 7.2. Rotor angle deviation between machine M2 and M1

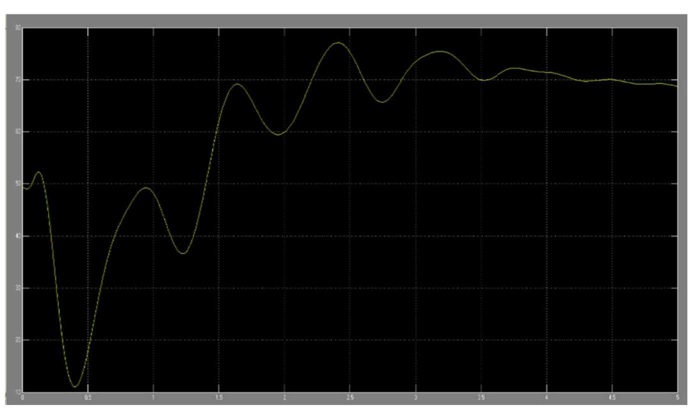

Figure 7.3. Rotor angle deviation between machine M3 and M1

Table 5. Comparison chart for stability

PSS/FACTS device	Location	Stability time for delta1_2 (in sec)	Stability time for delta2_3 (in sec)	Stability time for delta3_1 (in sec)
PSS	Connected with all machine	3.9	3.65	4.3
PSS+STATCOM	Between bus 4 and bus 5	4.2	4.1	4.3
PSS+UPFC	Between bus 4 and bus 5	3.7	3.42	3.8

V. CONCLUSION

The power system stability has been compared and discussed for improvement of a 3-machine 9 bus system by PSS, STATCOM & UPFC. After simulation results shown in Fig, a comparison is made between the above FACTS devices for stability enhancement of IEEE 9 bus system as shown in Table-5. From the Table-5, it is inferred that UPFC is the effective FACT device for stability enhancement over STATCOM and PSS as the post settling time obtained from the use of UPFC is less as compared to that obtained from STATCOM and PSS.

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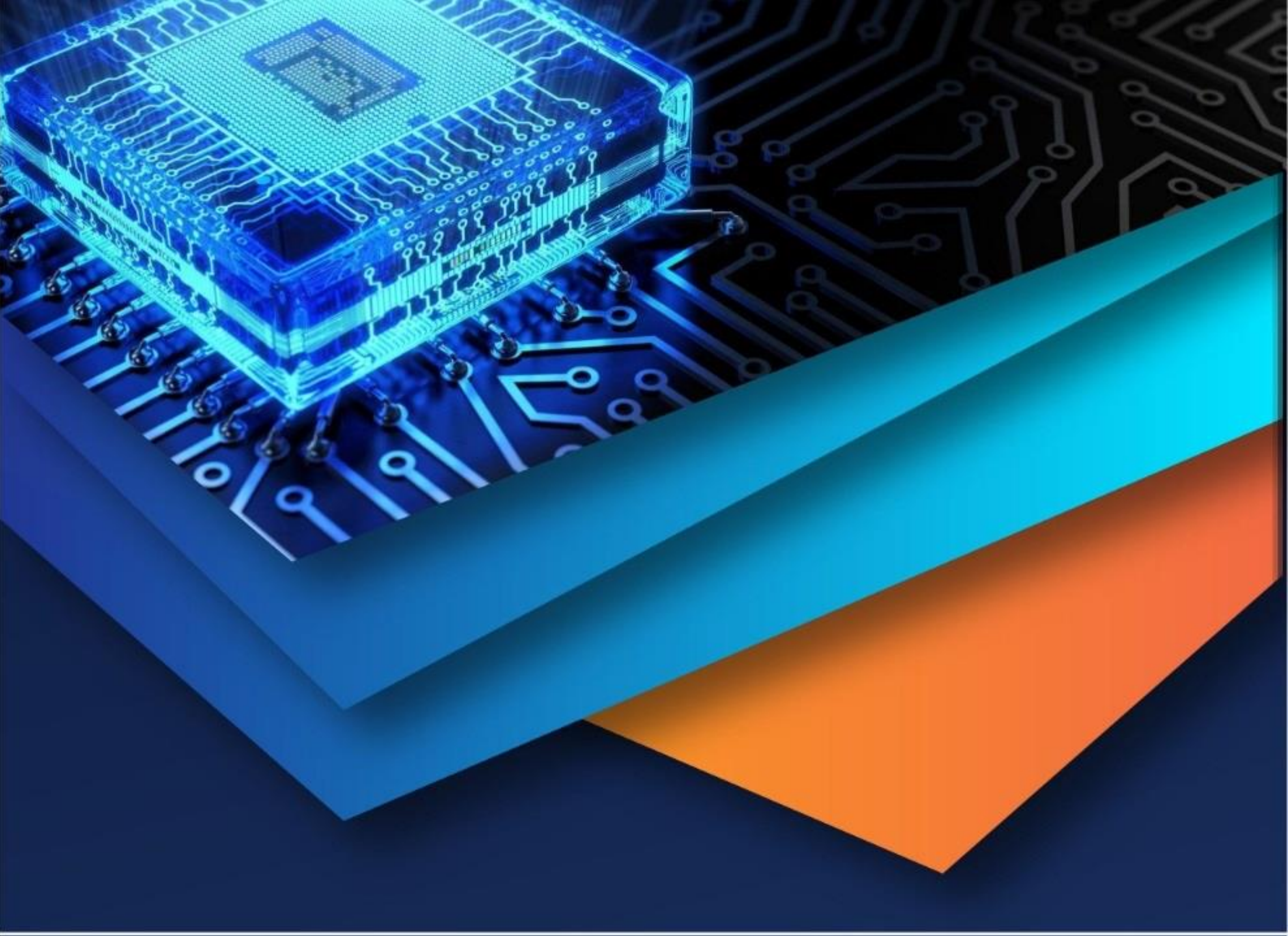

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